New Coolant for Indirect Refrigeration Based on Potassium Formate

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ACRC CR-11 December 1997

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Executive summary

This report shows the test results of supermarket display case when running with R404A (conventional refrigerant), Freezium and Pekasol 50 (used as a secondary refrigerant). Freezium was used in 45% concentration. Tests shown here are conducted on a 8 ft long single deck low temperature display case. The display case is defrosted by a electrical resistance heater in baseline operation and with warm secondary refrigerant in indirect refrigeration mode. The same heat exchanger is used for both test.

Tests are carried out at the Laboratory for Commercial Refrigeration, University of Illinois Air Conditioning and Refrigeration Center. Tests were performed using identical standard test procedure: ASHRAE Standard 72 - 1983 "Method of testing open refrigerators for food stores" (hereinafter abbreviated as Standard). This procedure is used in USA and is almost identical to procedure prescribed by ISO.

The criterion for the comparison was identical temperature of the product simulators when tested with different fluids. This is the primary purpose of display case: to maintain product at the prescribed temperature for the time being held in the supermarket. Tests show that the operation of the display case is better in the secondary refrigeration mode than in the baseline mode. This conclusion is based on several parameters that were compared:

- product can be maintained at the same temperature with higher temperature of secondary coolant than primary refrigerant in the baseline mode;
- product temperature is more uniform, specially during the defrost, than in the baseline mode;
- frost formation is more uniform and that leads to potential for the more dense fins;
- defrost period is significantly reduced.

The performance of the display case when using Freezium is slightly better than with Pekasol 50 but difference is in the range of experimental uncertainty. Nevertheless, pressure drop with Freezium at same temperature is just one half of value for Pekasol.

All tests performed with Freezium and Pekasol were in laminar flow regime because it was not possible to make flow turbulent at reasonable flow rates and pressure drops. Most of the tests with Freezium were in two extremes of reasonable flows: 100 g/s (v = 0.2 m/s, Re = 370) and 500 g/s (v = .75 m/s, Re = 1500). It is interesting that tests in lower Reynolds numbers show identical or better performance then in higher.

The pressure drops for the existing coil were measured. Viscosity was determined based on measured data using verified friction factor. Values determined show slightly lower viscosity for Freezium than stated in the manufacturers data.

Introduction

One of the vibrant areas of indirect refrigeration today is supermarket application, but industrial too. Freezium is one of the best candidates. Why supermarkets?

The approximately 30,000 supermarkets in the United States account for about 20% of CFC refrigerant consumption in this country. The food industry (wholesale and retail) also accounts for approximately 4% of electricity consumption in the nation. Implementation of indirect refrigeration could open options for ammonia and flammable refrigerants that could not be used in populated areas unless confined in low charge chillers. Indirect refrigeration could by replacing refrigerants that contribute to ozone layer depletion and global warming could minimize inventory of replacement refrigerants, reduce leaks, and increase energy efficiency and reliability.

We have tested two secondary coolant candidates: Freezium and Pekasol 50. Why are these fluids good candidates for low temperature applications?

The ideal secondary refrigerant should be: nontoxic, nonflammable, environmentally friendly, safe for contact with food, stable, compatible with common engineering materials, and have good thermophysical properties (high specific heat, high thermal conductivity, low viscosity, 5 to 10 cP, and high density) at low operating temperatures (-40°C).

Application range below -20°C and as low as -40°C is characterized by the existence of just a few real candidates, none of them being perfect. Silicon oils (polydimethylsiloxane), hydrofluoroether, some brines (potassium acetate, potassium formate). The trade-off for single phase candidates is in specific heat and viscosity: fluids with high specific heat have high viscosity and vice versa. Here is the brief overview.

Silicone oils

Applied in pharmaceutical industry, some industrial and commercial installations silicone oil has unfavorable thermophysical properties at low end (-40°C) compared to organic salts and hydrofluoroethers but are better than glycols. They are combustible. There is significant experience in different applications.

Organic salts (Potassium Formate and Potassium Acetate)

These are new brines and there is no significant experience in real applications. There are some problems with material compatibility but they have very good thermophysical properties, especially when compared to other candidates at low end of temperature range (-30 to -40°C).

Hydrofluoroethers

These have low viscosity at low temperatures and it is important that viscosity does not change significantly at low temperatures. These the only candidate of those mentioned here that could be used even at -100°C as a technically reasonable secondary fluid. They have poor specific heat, good material compatibility but some GWP.

Silicon oils could be excluded due to flammability as some other fluid not described here (d-limonene, ethanol, etc...)

Test facility and procedure

Laboratory for Commercial Refrigeration

The layout of the Laboratory for Commercial Refrigeration within Air conditioning and Refrigeration Center at the University of Illinois at Urbana Champaign is shown in figure 1. Tests were performed using display case in environmental chamber and specially designed low temperature chilling unit with hot liquid defrost.

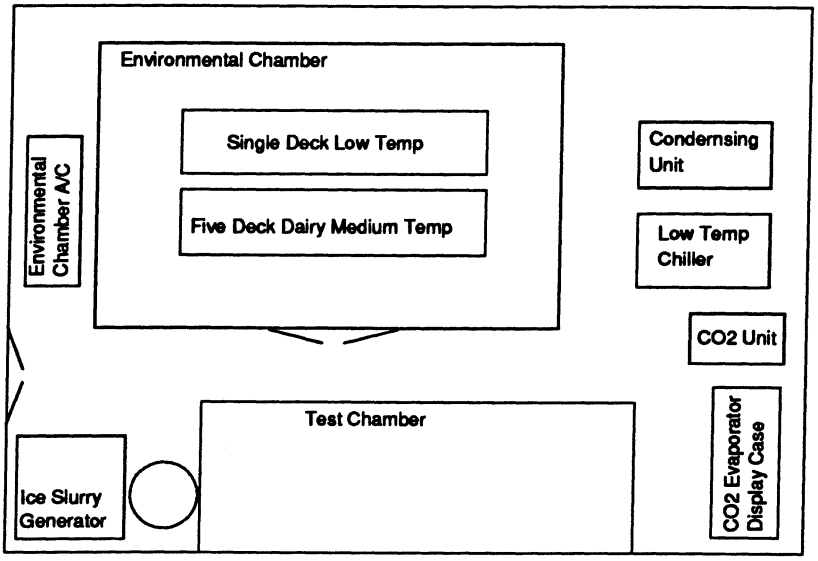


Figure 1. Layout of Laboratory for Commercial Refrigeration

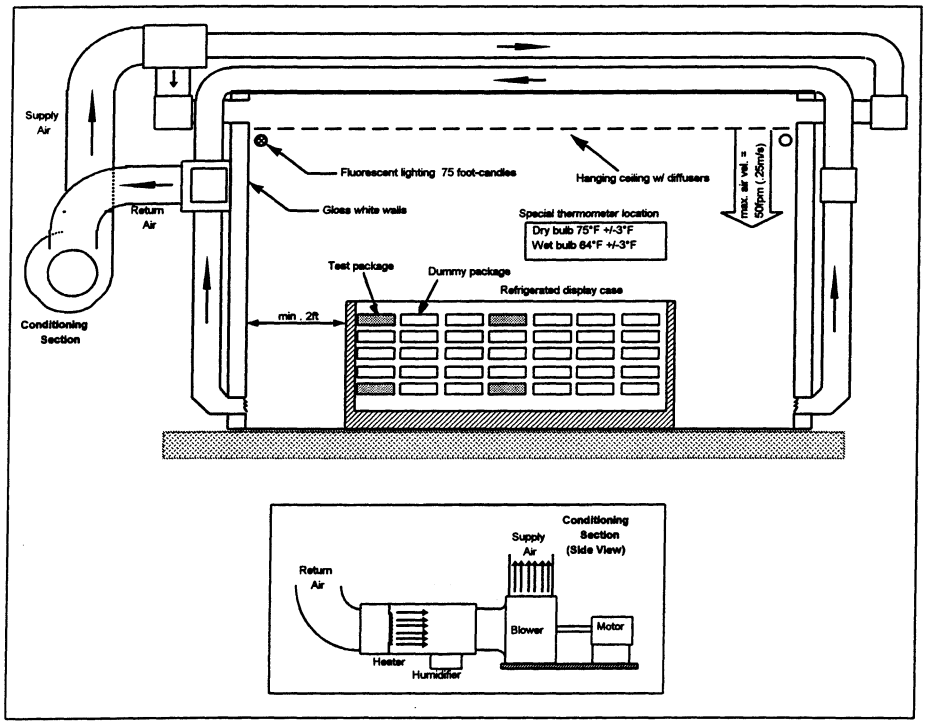


Figure 2. Experimental Test Facility - Environmental Chamber

Environmental chamber:

Two display cases are placed in the environmental chamber built to meet Standard requirements for testing display cases. The chamber is made out of polyurethane sandwich panels with a thickness of 3 3/4 inches. According to the Standard the environmental chamber has white gloss walls, air velocity is 0.14 m/s at 3 m from the floor (req. max. 0.25 m/s) and is illuminated by fluorescent bulbs 836 lux (required min. 800 lux).

The schematic of the environmental chamber is given in the figure 2. Air flows from the ceiling through twenty-four distributors. Return air enters six vents at the bottom of the chamber.

The refrigerated case is operated in the prescribed ambient environment (T_{db} = 23.9 ± 1.7 °C, T_{wb} = 17.8 ± 1.7 °C). Conditioning of the circulating air (heating and humidification) is completed before entering the blower.

View to the environmental chamber is shown in figure 3.

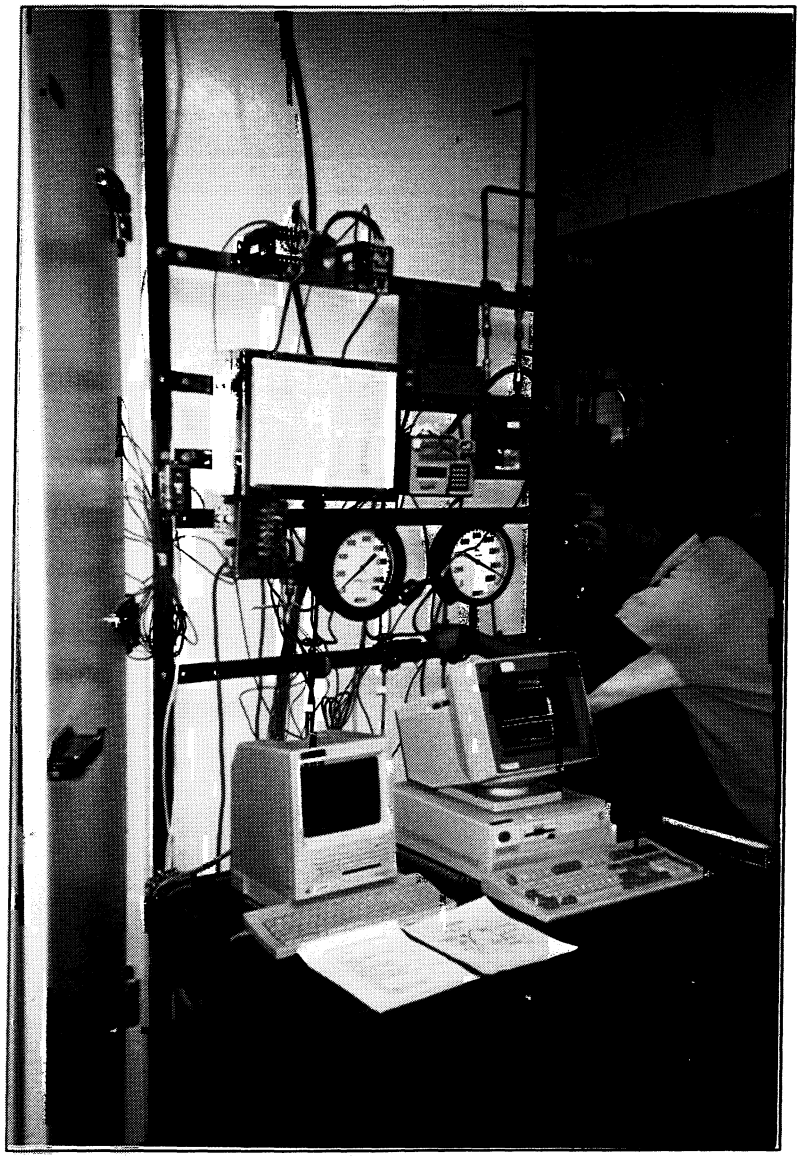


Figure 3. Environmental chamber and data acquisition system being operated by W. Terrell Jr.

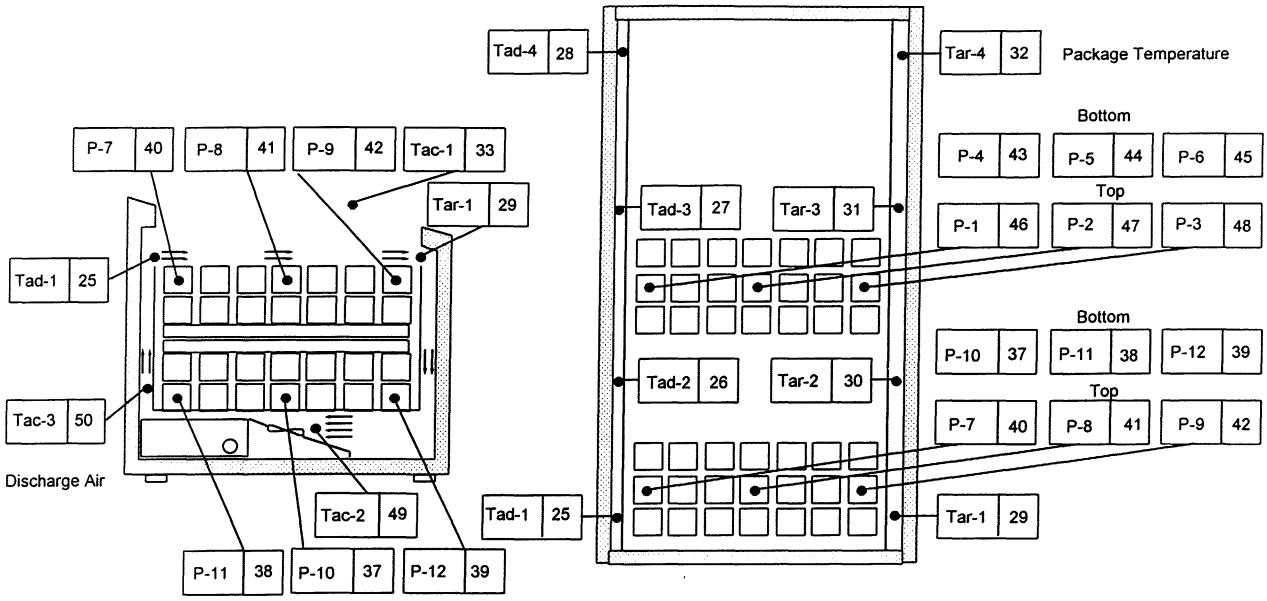


Figure 4. Position of the test packages in the display case

Figure 5. Single deck low temperature display case in the environmental chamber

Test packages are placed in the display case as prescribed by Standard and shown in the figure 4. There are twelve product simulators (test packages) total. Other numbers in boxes represent data acquisition channels. Figure 5 shows the view to the display case tested.

Refrigeration and procedure for baseline test

Adequate refrigerant flow to have minimum superheat for stable operation and liquid refrigerant temperature is supplied as demanded by the case. This is achieved by changing the suction pressure and adjusting the thermo expansion valve to obtain maximum flow rate and still keep superheat stable. The display space is filled with test packages and dummy packages. After repeatable conditions occur, the recorded data for a 24 hour period is treated as one test level (defined by Standard). Repeatability of test conditions are determined by $\pm$ 0.2 °C difference in package temperatures at the beginning and end of the 24 hour period. Package temperatures generally take longer to reach steady state compared to other parameters (air and refrigerant temperatures).

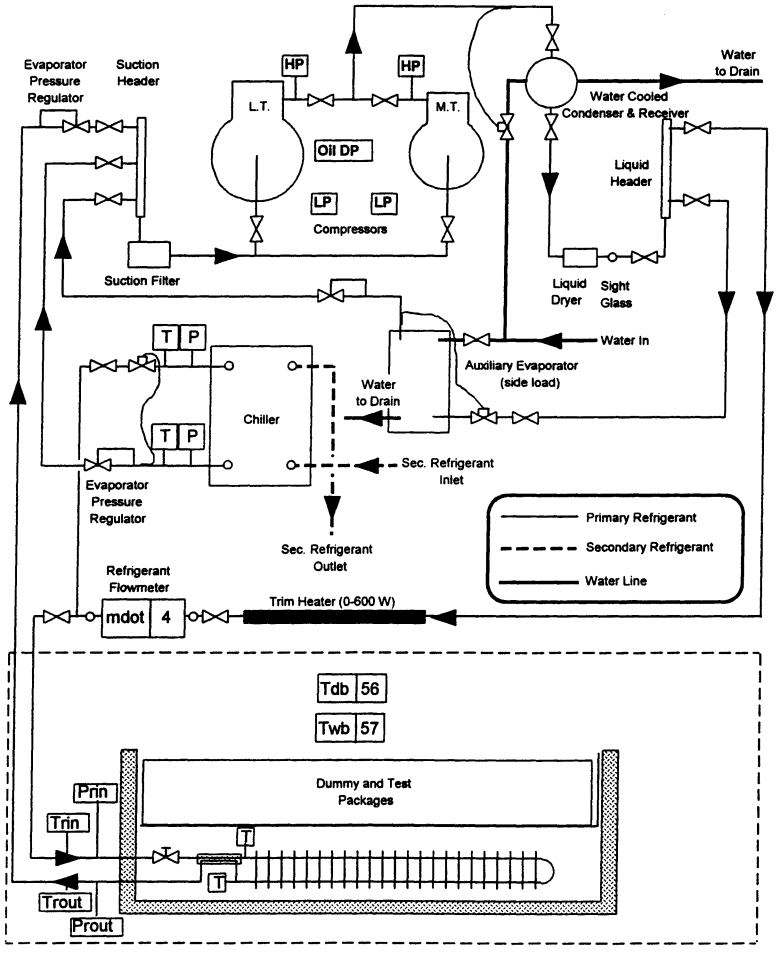


Figure 6. Baseline Schematic

The schematic of the test facility in baseline mode is shown in figure 6. Two compressors are in parallel for which only one operates at a given time. The condenser is shell and tube water cooled.

Procedure for tests with secondary refrigerant

For test with secondary fluids, two additional evaporators (one brazed plate and other shell and tube) were added in parallel to the condensing unit to serve as the chiller for the fluids.

The secondary loop shown in figure 7. consist of two sections, the "cold" loop (refrigerating loop) and the "warm" loop (defrost loop).

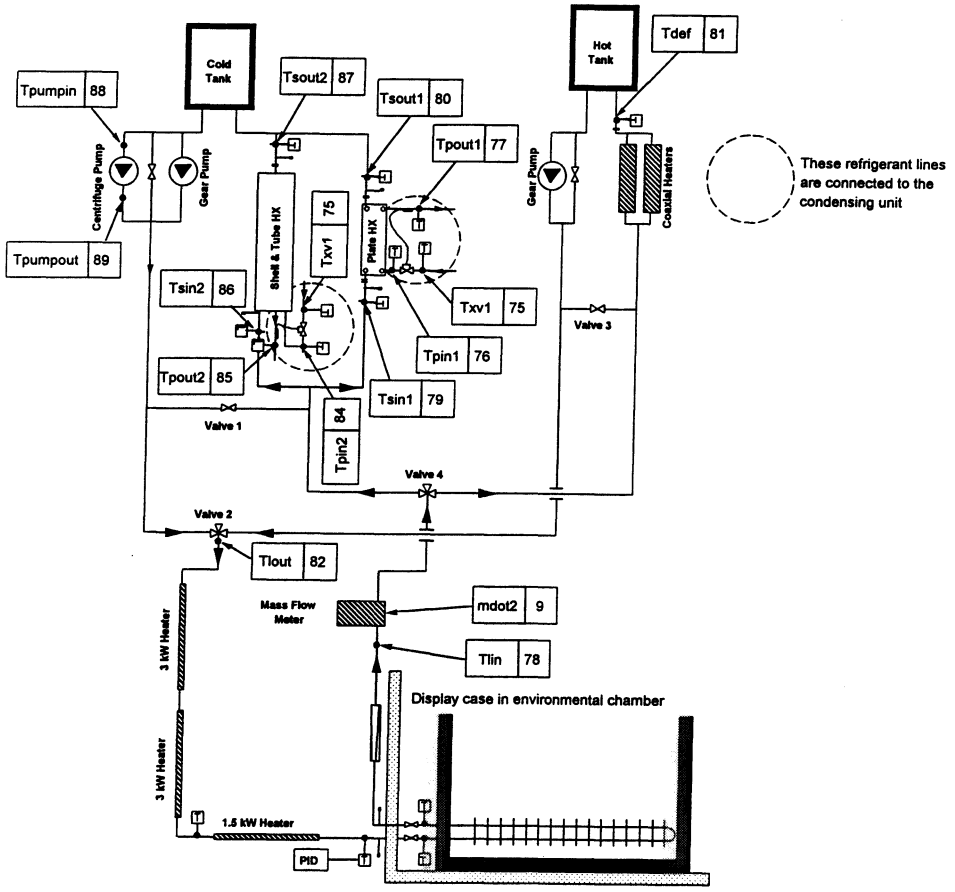


Figure 7. Schematic of the Secondary Loop

The "cold" loop serves to provide refrigeration in the test period. Secondary fluids are cooled in the chiller (brazed plate or shell & tube evaporator). The fluid is pumped from an expansion tank through coaxial heaters. Last heater is used for fine adjustment of the fluid temperature and also for on-line determination of the specific heat of the secondary refrigerant. The fluid then enters the display case and flows back into the heat exchanger. Temperatures are measured with thermocouples at the inlet, coil passes, and outlet. The pressure difference across the heat exchanger is measured using a pressure differential transducer. The mass flow rate is measured using a Coriolis type mass flow meter at the exit from the display case.

The "warm" loop consist of two coaxial heaters, an immersion heater, an expansion tank, and the pump. Some time before defrost of the display case, the heaters are turned on to warm up the

fluid. This fluid is circulated around the loop at the starting temperature until defrost starts. When defrost begins, valves are switched so that hot fluid enters the display case (while the cold loop is closed). When defrost is completed, the system is switched back to the cold loop. All conditions that applied to the baseline test (based on the Standards) apply to secondary test.

Test with secondary refrigerant has coolant velocity as the additional parameter compared to baseline tests. At low temperatures most fluid candidates considered can not be operated in turbulent mode with a reasonable pressure drop.

Heat exchanger

The performance of the heat exchanger is monitored in order to collect data useful for the heat exchanger optimization. Figure 8 shows the positions of the thermocouples attached to the heat exchanger. Heat exchanger is typical for this application: aluminum plate fins 2 and 4 fpi, 5/8 in copper tubes in three circuits each having 8 pipes 7 ft long. Details are given in Apendix 6.

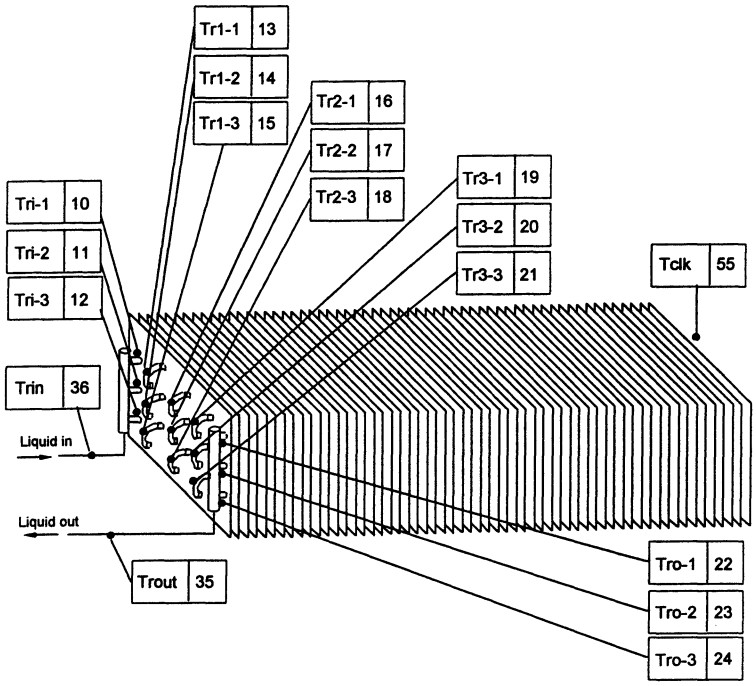


Figure 8. Heat exchanger thermometer positions

Data acquisition system and instrumentation

Instruments are connected to three Campbell AM416 Relay Multiplexers, which in turn are connected to and controlled by a Campbell 21X datalogger. The datalogger is connected via RS232 to a PC, where the data can 1) be viewed on various graphs in real time and 2) is finally stored (as ASCII comma separated text). A full explanation of data acquisition system and instrumentation can be found in Appendix 4.

Fluids tested

Three fluids were tested: R404A (as a baseline fluid), Freezium (potassium formate), and Pekasol 50 (potassium acetate).

Secondary refrigerants were tested in concentration needed for -40°C: potassium formate with 45% and potassium acetate with 50%.

Procedure to compare the performance of the display case when operating with different refrigerants

Approach taken in this project is to use existing, state of the art display cases, run the baseline tests with refrigerant and oil as in conventional operation, and compare it later to operation with single phase secondary refrigerant. In order to exclude any potential for criticism we performed comparative tests of display case with secondary refrigerant with the same heat exchanger that was evaporator, just substituting distributor with the inlet. Heat exchanger surface when operating with secondary refrigerant is reduced by removing suction line heat exchanger used in baseline tests.

One of the key issues is what criteria will be used to compare the fluids. Our approach is to compare performance based on product temperature because the purpose of the display case is to maintain product temperature at required level. Some objection could be raised due to the fact that it is easier to measure air temperature in real applications (in a store).

Standard prescribes presentation of three package temperatures: the coldest test package average (average temperature of the coldest package in the test period), the warmest test package average and integrated average. The coldest test package is usually at the bottom of the display case (P4), right above the evaporator (heat exchanger), while the warmest package is on the top (P8 or P2). The critical temperature is obviously the warmest test average. Figure 4 shows the position of test packages in the display case.

The performance of the heat exchanger is monitored in order to collect data useful for the heat exchanger optimization. Figure 5 shows the positions of the thermocouples attached to the heat exchanger.

Description of test results

Operating temperatures:

Figure 9 shows the performance of the display case when operating with R404A and with Freezium (potassium formate) as the secondary refrigerant.

Temperature at the inlet to the evaporator for both baseline and indirect refrigeration mode is displayed at the abscissa while ordinate represents the package temperatures. Three lines are shown for each refrigerant. Dashed lines represent performance in baseline mode, while solid lines represent performance with the secondary refrigerant (potassium formate). This diagram shows that the same product temperature could be achieved by significantly higher temperature of the secondary refrigerant at the inlet to the coil.

For example, to maintain required frozen food product temperature in conventional store evaporation temperature of R404A is typically -28°C. At this case in our baseline tests discharge air temperature is -24°C °C and the temperature of the warmest test package is -7°C. The same product temperature could be achieved with potassium formate at the inlet of only -20.5°C. In ice-cream low temperature range difference is reduced. At -10°C warmest test package temperature the increase of operating temperature at the inlet is from -32°C in baseline to -27.5°C. At lower end this difference gets even smaller.

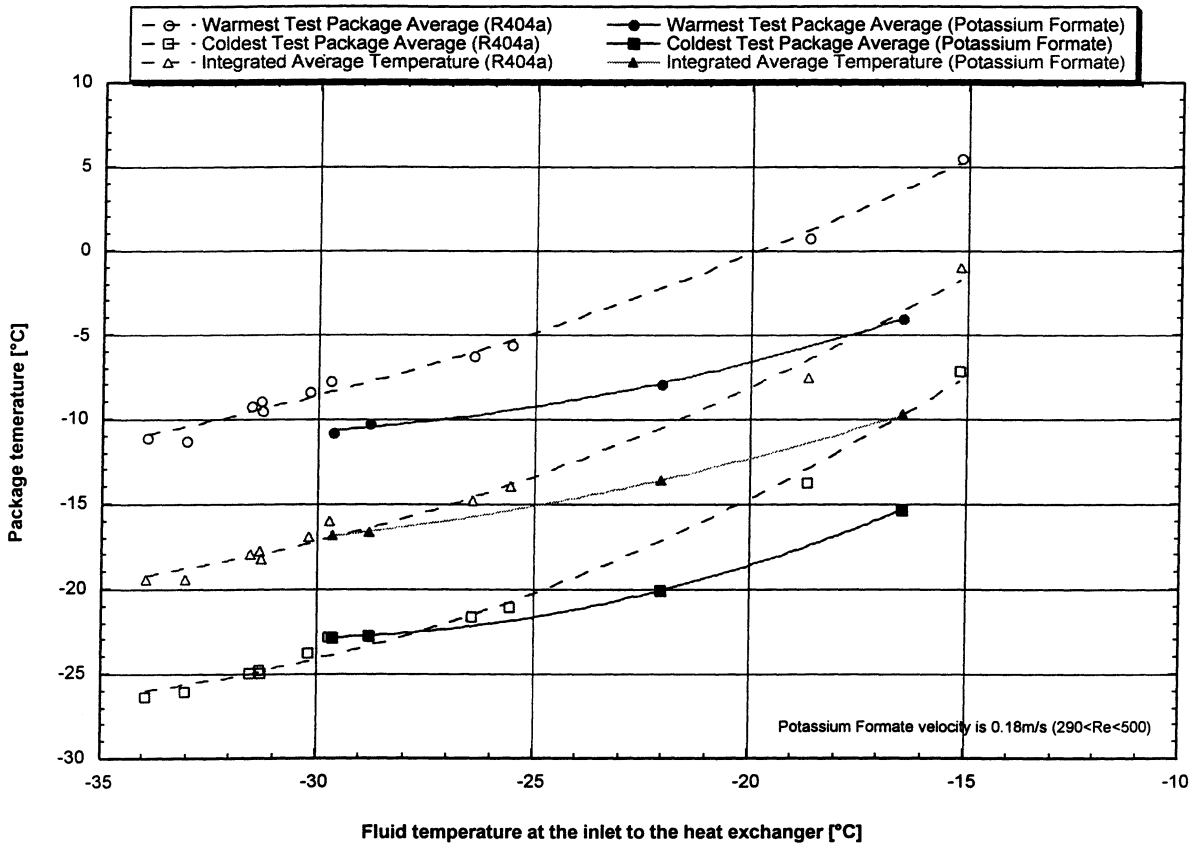


Figure 9. Package temperatures as a function of the inlet temperature to the heat exchanger

Tests with secondary refrigerants are conducted with different fluid velocities in the heat exchanger. Neither potassium formate nor potassium acetate could run in turbulent mode with reasonable pressure drop. Since heat transfer coefficient in laminar regime is not a function of the velocity, only the glide has influence to the heat transfer. There is the question of what flow rate would give the optimum between heat transfer and pressure drop. Figure 10 indicate that lower velocities are closer to the optimum. Graphs show package temperatures for two flow rates for each secondary refrigerant.

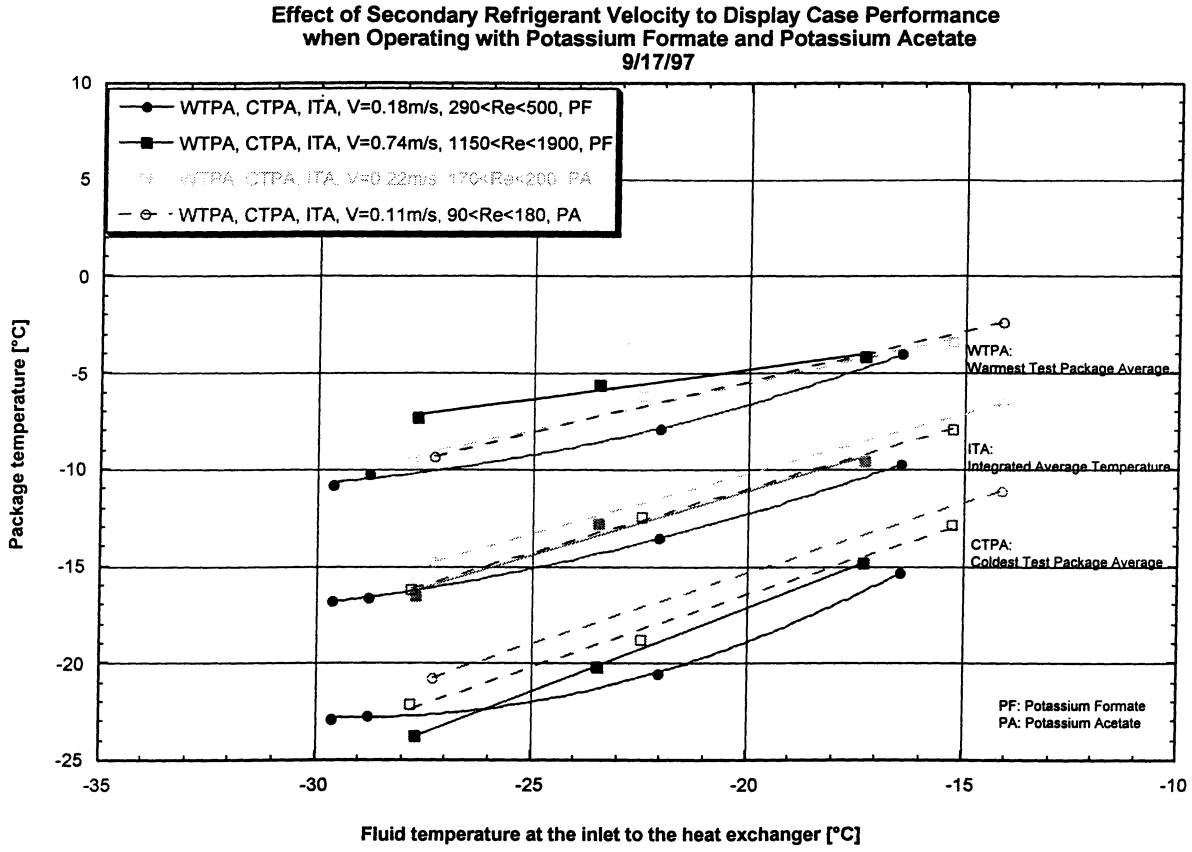


Figure 10. Effect of velocity on package temperature when case is served with Freezium and Pekasol 50

Defrost

Experiments show that the defrost period is significantly reduced when warm secondary refrigerant is used instead electrical heaters to melt the frost.

For baseline tests, the range of defrost time was from 12 to 21 min. The termination of the defrost cycle was controlled by a clixon installed on evaporator pipe.

Defrosting of heat exchanger served with secondary refrigerant goes through phases:

1. Pipes are defrosted first in app. one minute. It is the time for secondary refrigerant to flow through the coil.
2. Fins are defrosted in next 2-3 min.
3. Drip pan requires more time to defrost. Termination signal was set at 10°C for the critical position between the fan cover and the drip pan.

The sequence of the defrost with warm Freezium is shown in figures 11 through 18.

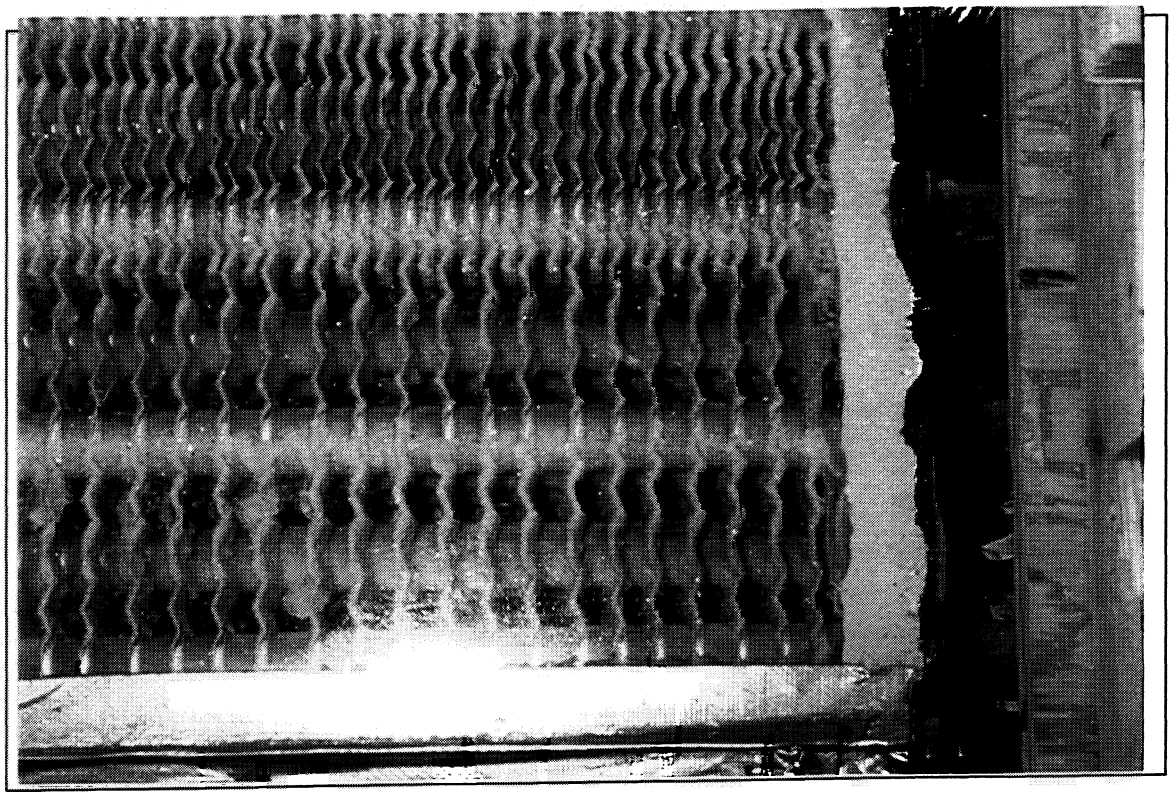


Figure 11. Heat exchanger before the defrost

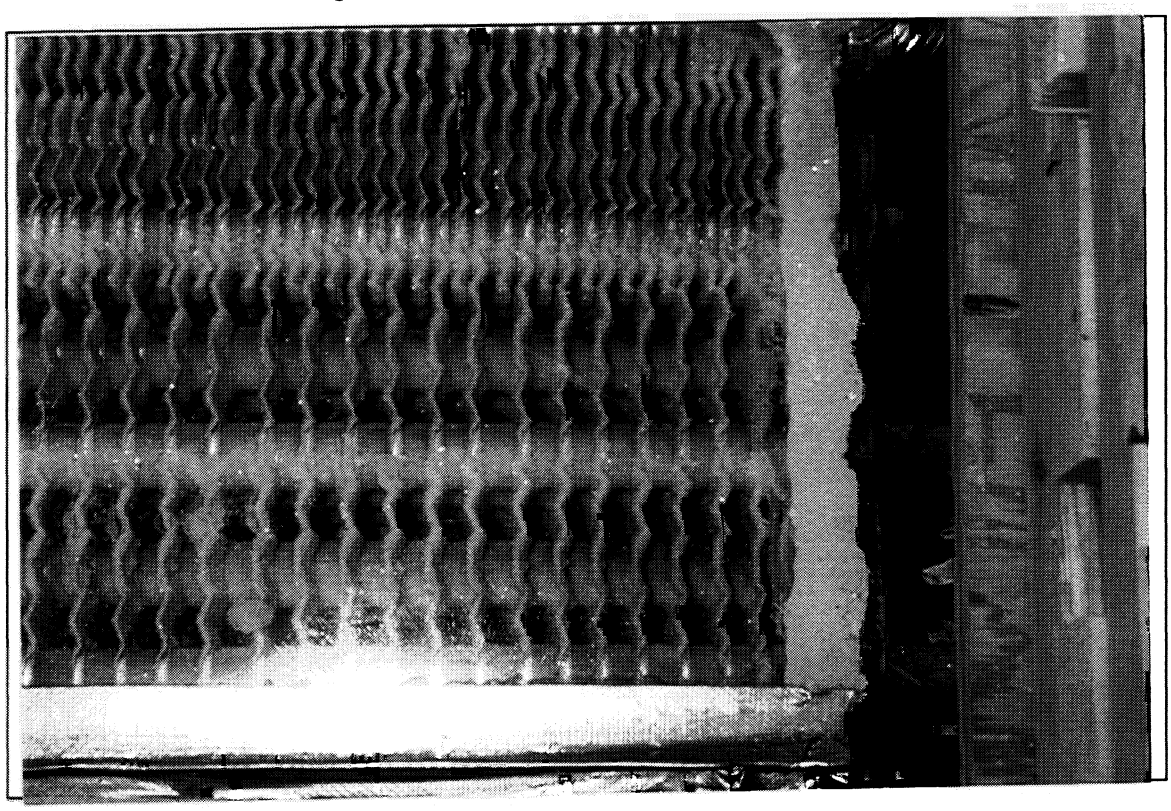


Figure 12. Heat exchanger 60 sec after: some pipes are defrosted

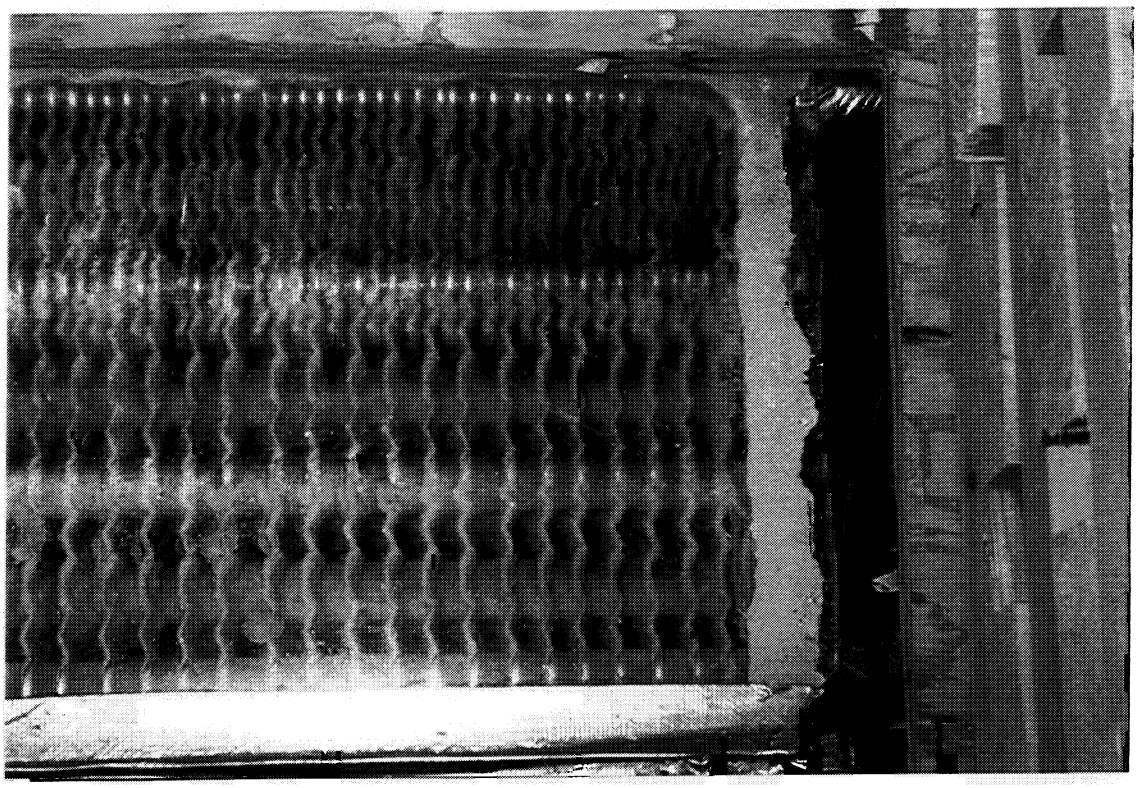


Figure 13. Heat exchanger 90 sec after: pipes are defrosted and last fins

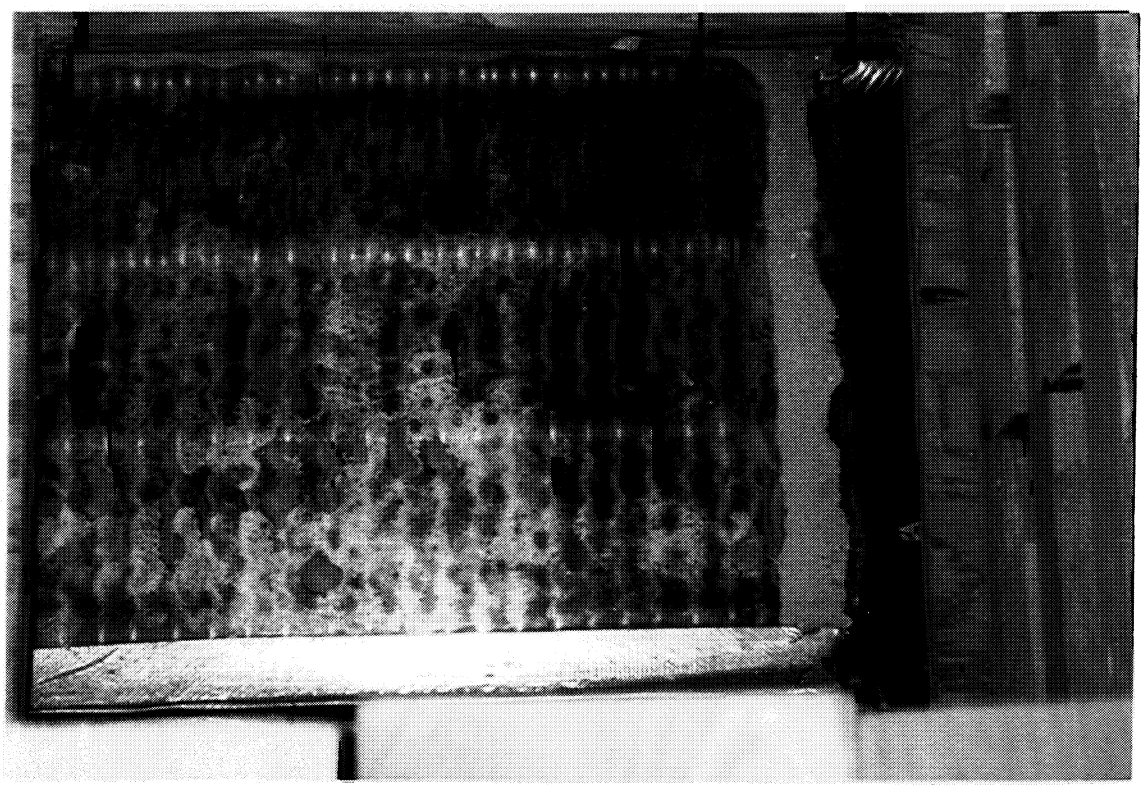


Figure 14. Heat exchanger 2 min. after: heat exchanger is almost completely defrosted. Fog indicates condensation of the steam on the cold Plexiglas surface as a clear sign of partial overheating

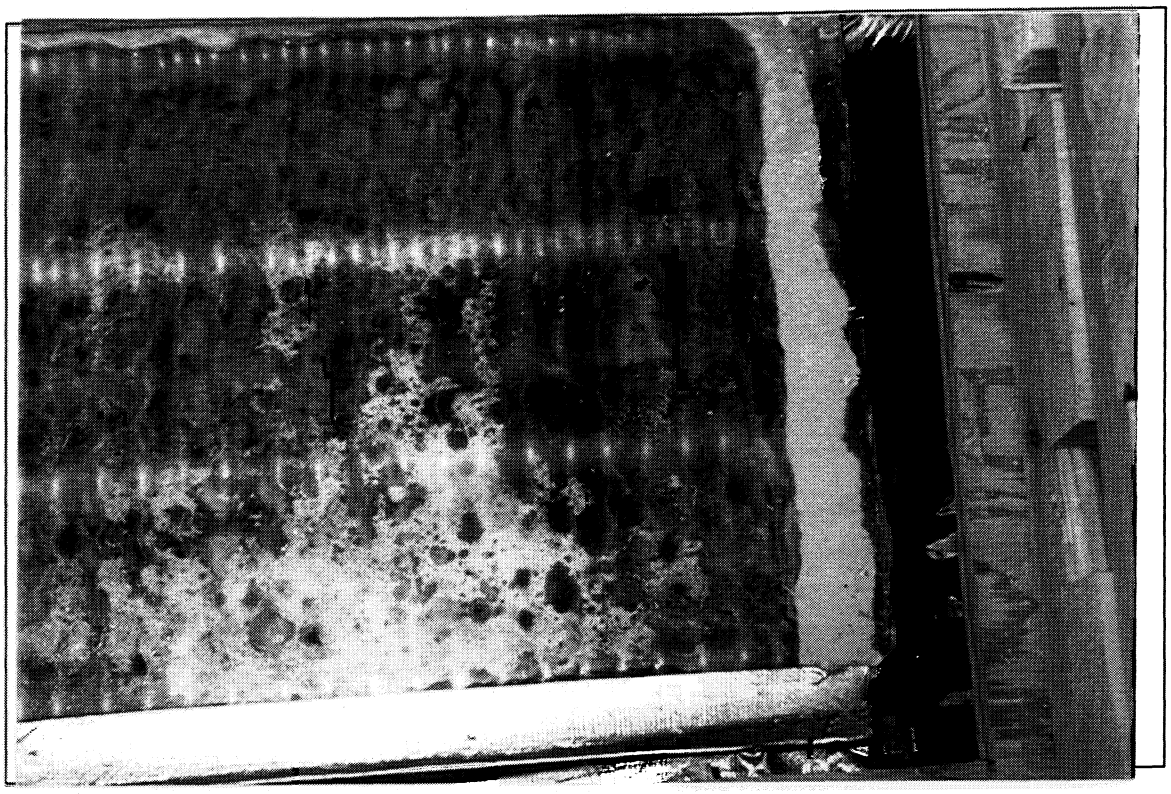


Figure 15. Heat exchanger 3 min. after: almost ready for termination

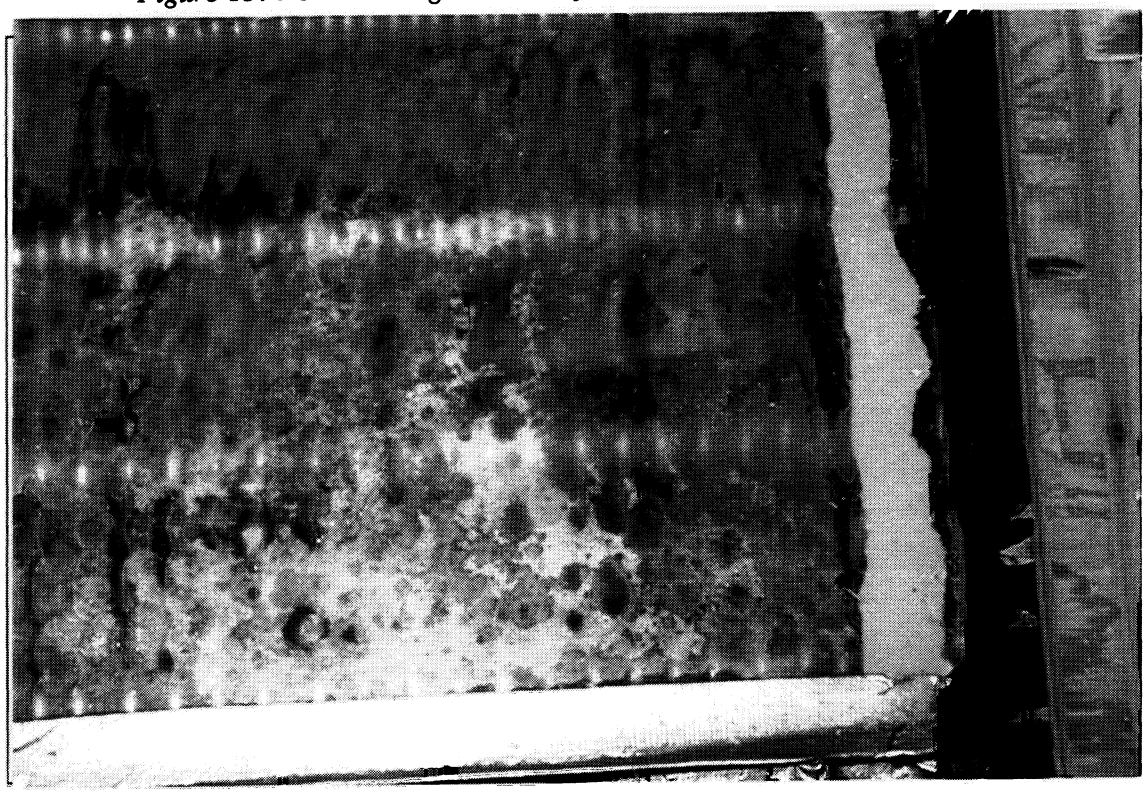


Figure 16. Heat exchanger 3 min. 44 sec after: termination of the defrost. Sometime it was not enough - some frost was still unmeleted at the bottom of the drip pan

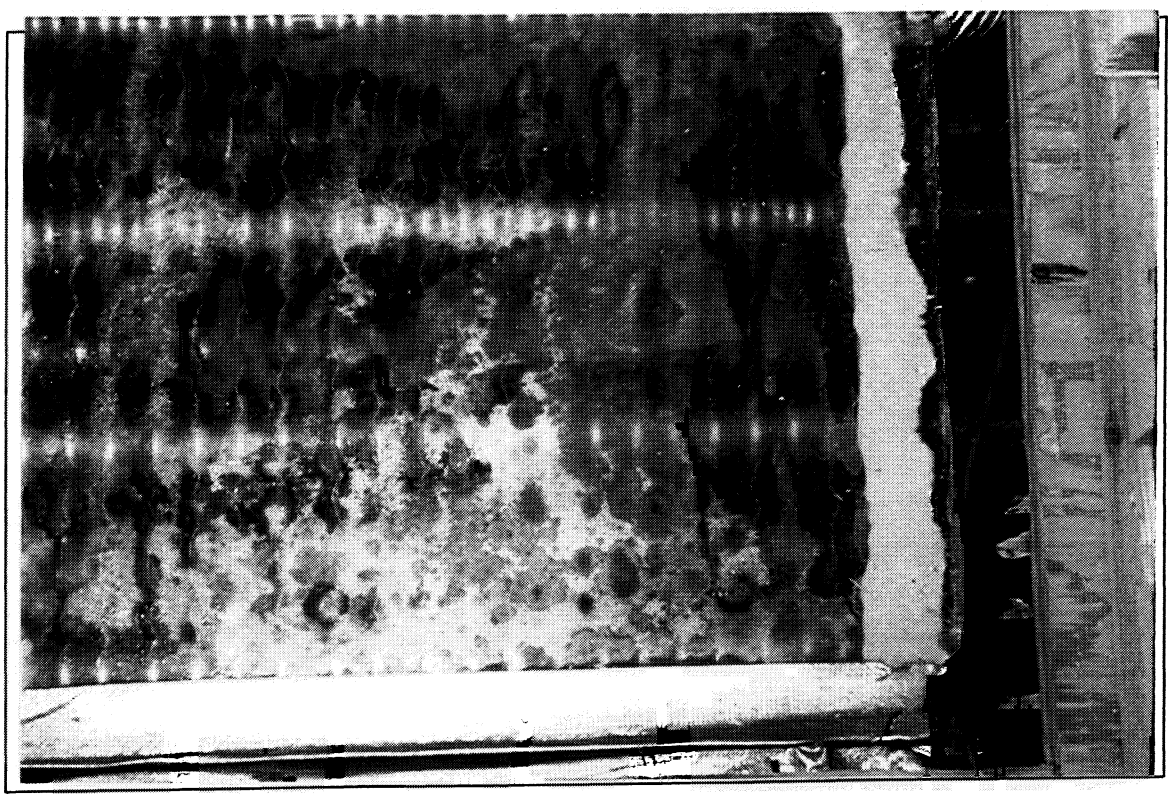


Figure 17. Heat exchanger after 4 min.

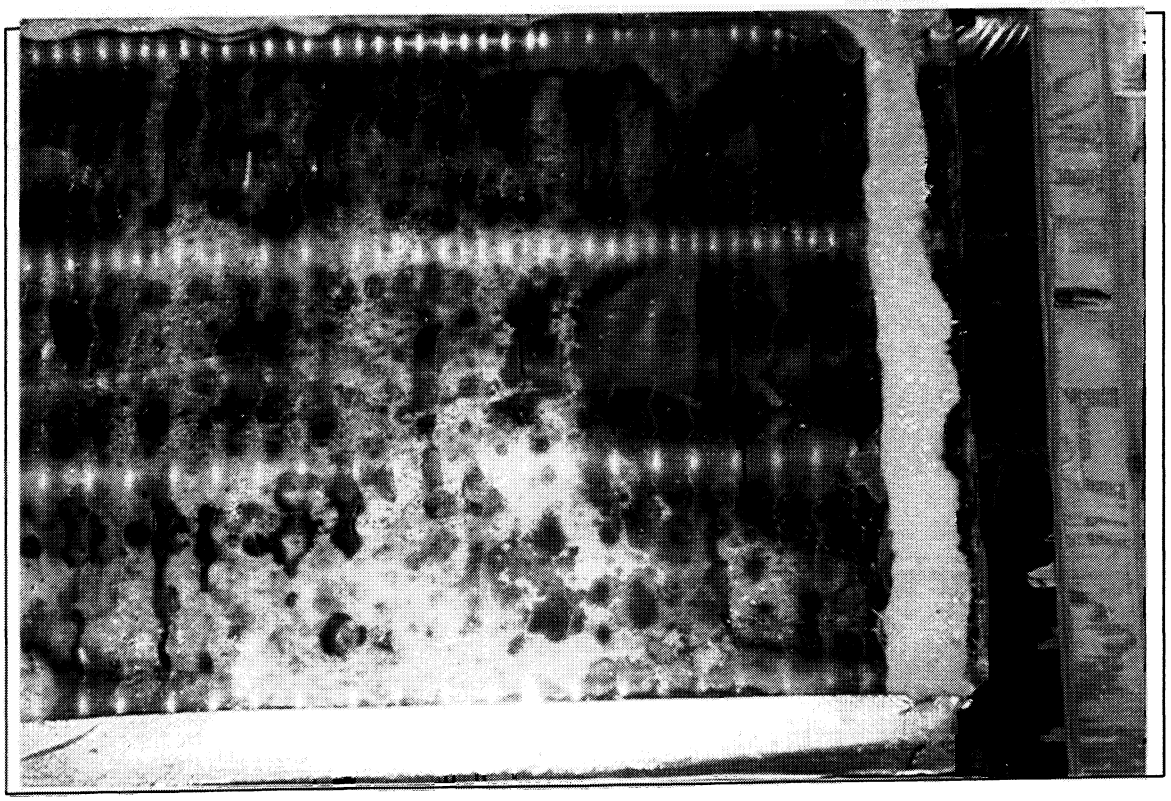


Figure 18. Heat exchanger after 5 min.

Total defrost time is 10 to 15 min. due to slow drip pan defrost. This could be improved by adding additional small defrost heater similar in design to those used in cool gas defrosted cases. There is no reason why total defrost time could not be just slightly longer than time needed for fin defrost.

Inlet temperature of the secondary refrigerant was 30°C and the flow rate was slightly higher than in the refrigeration mode.

Reduction of defrost time has several positive effects. One is more uniform temperature profile in the product stored in display case.

Figures 19 and 20 show the typical temperature profiles for air and packages in the same display case when operating at similar product temperatures in DX (conventional) mode and in secondary loop mode.

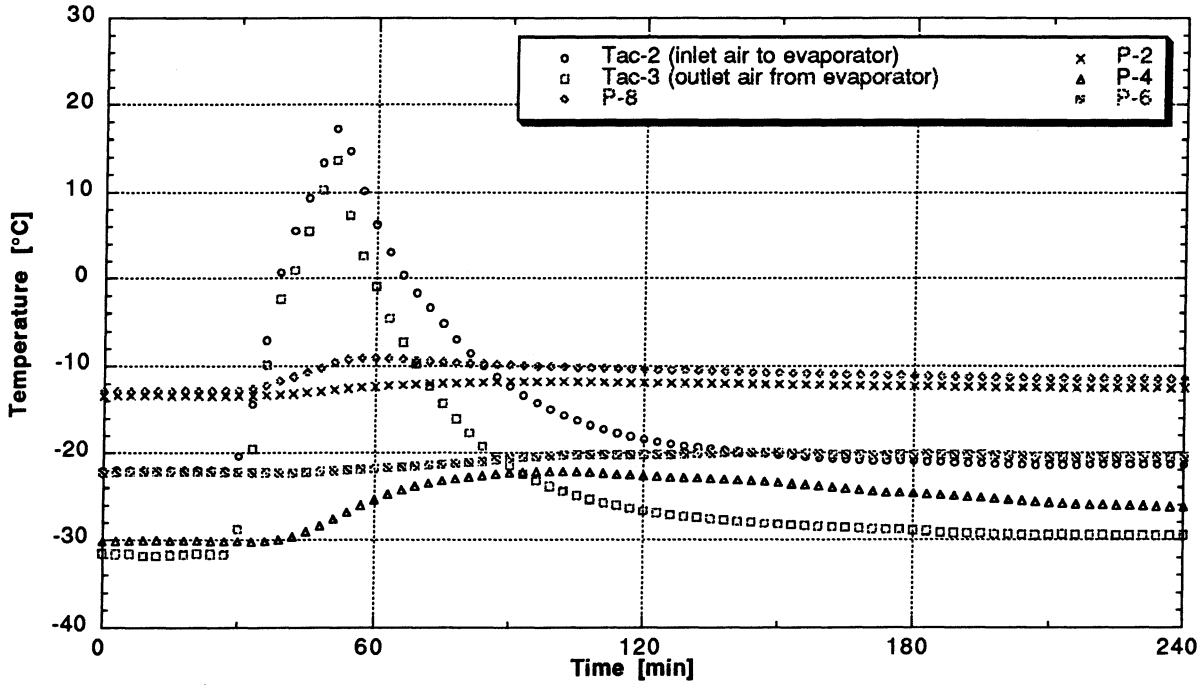


Figure 19. Temperatures of the coldest packages in the display case (P4, P6) and the warmest (P2, P8) and air in and out from the evaporator (Tac-2 and Tac-3) in defrost period. Defrost by electrical heater. Refrigerant is R404A. Greatest variation in P4 temperature is approx. 8°C

Figure 19 shows the difference in temperatures of the packages at the different locations in the baseline (DX) mode both before and during the defrost. The temperature in the center of the coldest package is being changed by approx. 8°C during the defrost. This change is greater at lower operating temperatures for colder packages. At higher operating temperatures warmer packages (more exposed to the ambient air) experience greater change in temperature during the defrost.

Different frosting pattern is demonstrated in figures 21 and 22. Figure 21 shows the frosted evaporator after 24 hours of operation with R404A in baseline mode while figure 22 shows the same heat exchanger when served by Freezium. In second case frost is more uniform.

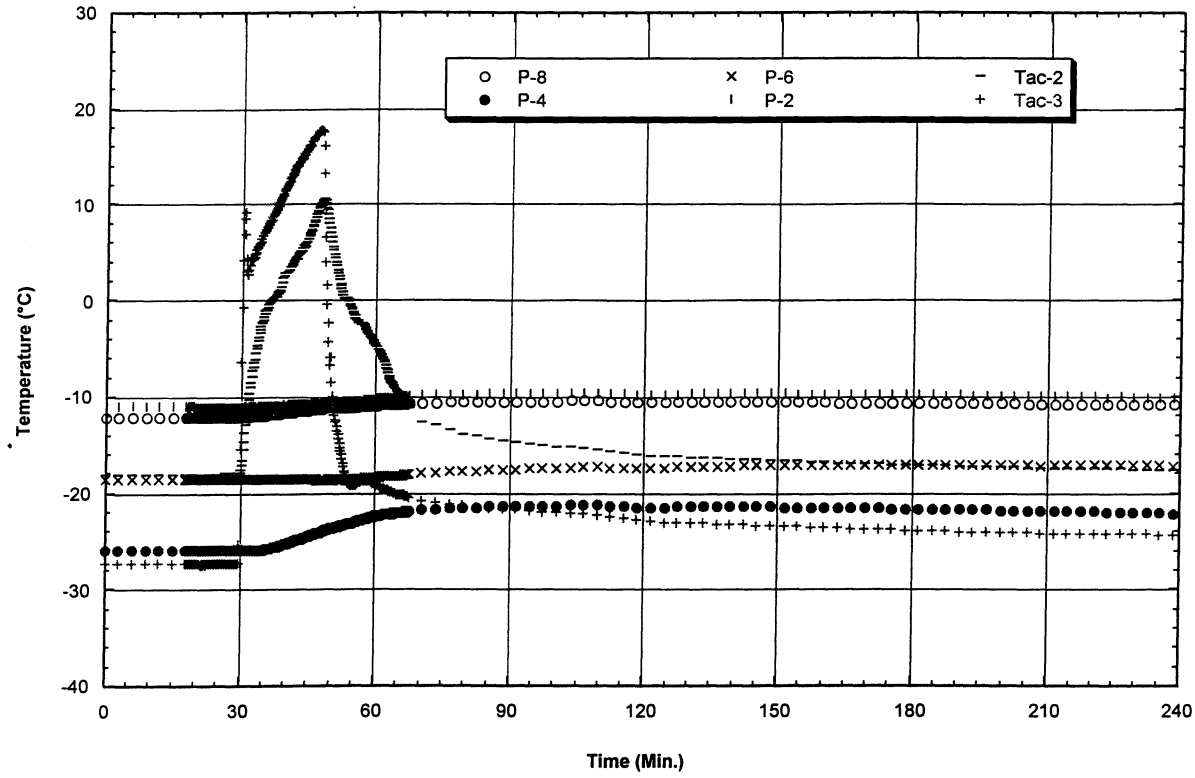


Figure 20. Temperatures in the same display case as shown in Figure 10 but refrigerated by cold brine. Defrost is by warm secondary refrigerant. Greatest variation in coldest package temperature (P4) is lower - approx. 4.5°C.

Comments on performance

Figure 9 shows that the same product temperature could be achieved with a higher temperature of the secondary refrigerant compared to evaporation temperature in baseline mode. Also the load is reduced due to more efficient defrost. Shorter defrost time decreases heat input into the refrigerated space (heat load later) and increases effective running time (refrigeration capacity).

Higher coil surface temperatures are beneficial and should cause less frost. The temperature glide (due to finite specific heat) and almost constant heat transfer coefficient on the refrigerant side results in more uniform frost deposition. More uniform frost will allow for greater fin density (more surface in the same volume). Additionally, more uniform frost results in a smaller reduction of air flow as defrost time is being approached, thus increasing both air side heat transfer and temperature difference compared to operation in DX mode.

The defrost cycle should be terminated when the last ice particle is melted from the fins. Therefore, uniform frost deposition exhibits another advantage in shortening the defrost period.

Figure 21. Evaporator in a display case when running with R404A after 24 hour operation in low temperature regime under conditions prescribed by ASHRAE Standard 72. Frost is poorly distributed. Deposition is greater in regions with higher heat transfer coefficient.

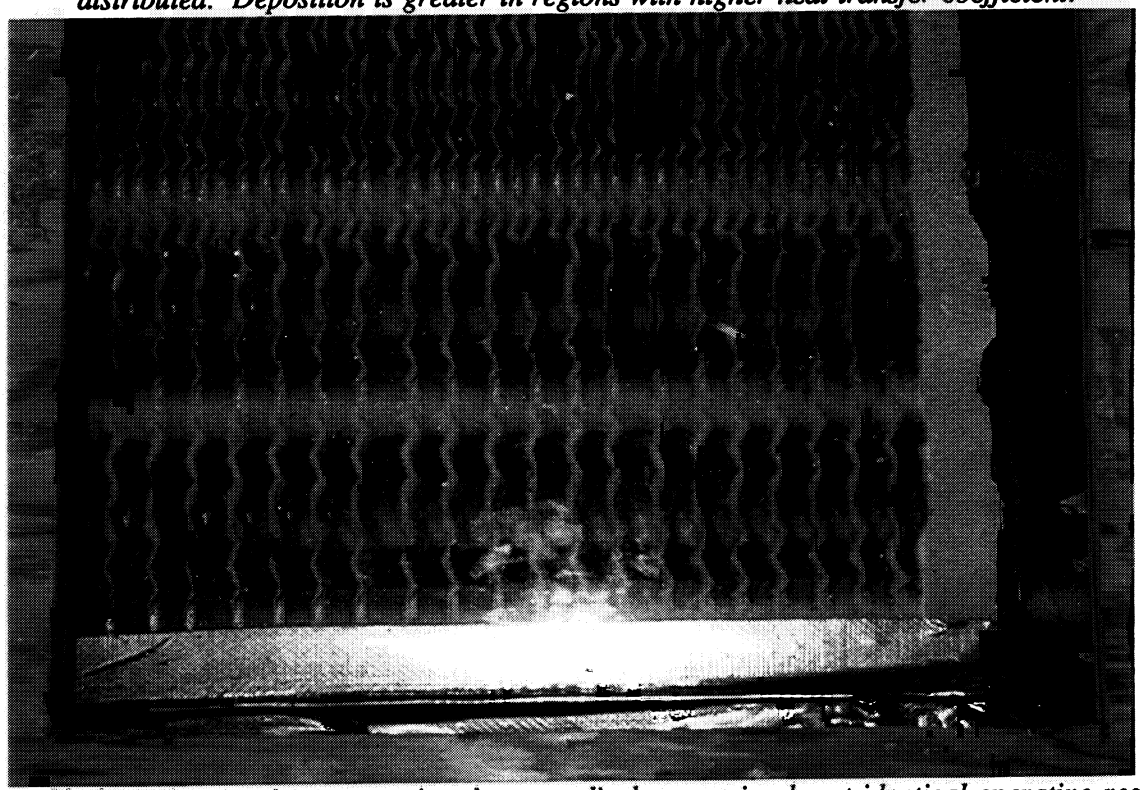


Figure 22. Same heat exchanger serving the same display case in almost identical operating regime as shown in Figure 7. Heat exchanger is modified and runs with single phase secondary refrigerant. Photo is taken after 24 hours of operation, just before the defrost. Better frost distribution compared to baseline case.

Besides very good results in thermal aspect, Freezium and Pekasol 50 exhibits some problems in material compatibility. This could be summarized as:

- We have observed very aggressive reaction to zinc;
- Copper pipes in contact with copper were covered by blue/green (somewhere some white layers formed at the top of this coating);
- All steel surfaces where coating was damaged corroded significantly;
- Some gaskets in valves were damaged and valves leaked.

Besides that, some separation of the brine is observed. Most of separated parts are collected at the bottom as a very light white crystal like material. The smaller component floats on the top in the form of the white foam. Filter/strainer required periodic cleaning.

Conclusion:

Test results shown in figure 10 as the most indicative show that the performance of the display case served with potassium formate at low temperatures is better than in baseline mode (using the same evaporator as a heat exchanger). Results are encouraging and tests are continuing with new fluids and better designed heat exchangers for the single phase secondary refrigerants.

Appendix 1

Baseline test data

Table of Contents

DATA	072396.a	072396.b	072396.c	072396.d	072396.e	81296.1	81496.1	82696.1
mdot [g/s] =	7.03	6.98	6.93	6.87	6.91	7.44	7.76	6.61
Pressures								
Prin [kPa] =	1879.77	1884.42	1878.07	1874.93	1875.69	1843.22	1901.74	1940.51
Prout [kPa] =	169.97	168.68	167.7	167.16	168.14	173.11	179.95	206.56
Power Usage								
W1 [kPa] =	305.76	307.12	305.89	305.12	305.55	308.83	306.56	297.56
W2 [kPa] =	0.03	0.03	-0.03	0.04	0.04	-0.03	0.07	0.14
General Temp								
Tref [°C] =	25.33	25.37	25.3	25.28	26.45	26.19	26.29	26.4
Tdb [°C] =	24.73	24.79	24.75	24.79	25.67	25.41	25.33	26.24
Twb [°C] =	17.86	19.11	21.39	22.88	20.22	18.81	19.29	20.23
Case Inlet								
Trin [°C] =	30.80	30.83	30.56	30.43	30.98	31.87	29.15	30.36
Hot Fluid In								
Trhx-1 [°C] =	25.23	25.17	24.97	24.8	25.53	26.62	24.38	25.32
Hot Fluid Out								
Trhx-2 [°C] =	9.17	9.13	8.98	8.73	9.43	9.31	-2.59	8.72
Evap Inlet								
Tri-1 [°C] =	-33.94	-34.02	-34.15	-34.28	-34.16	-33.41	-32.58	-29.31
Tri-2 [°C] =	-34.00	-34.08	-34.21	-34.35	-34.2	-33.42	-32.67	-29.38
Tri-3 [°C] =	-33.72	-33.93	-34.02	-34.13	-33.99	-33.22	-32.34	-28.95
Tri av [°C] =	-33.89	-34.01	-34.13	-34.25	-34.12	-33.35	-32.53	-29.21
Pass 1								
Tr1-1 [°C] =	-33.37	-33.45	-33.56	-33.69	-33.56	-33.11	-32.38	-29
Tr1-2 [°C] =	-33.55	-33.63	-33.73	-33.85	-33.71	-33.12	-32.36	-28.99
Tr1-3 [°C] =	-33.33	-33.4	-33.48	-33.58	-33.43	-32.99	-32.29	-28.89
Tri av [°C] =	-33.42	-33.49	-33.59	-33.71	-33.57	-33.07	-32.34	-28.96
Pass 2								
Tr2-1 [°C] =	-32.56	-32.62	-32.68	-32.82	-32.64	-32.28	-31.69	-28.14
Tr2-2 [°C] =	-31.37	-31.49	-30.42	-29.89	-29.58	-32.86	-32.08	-28.52
Tr2-3 [°C] =	-32.66	-32.6	-32.43	-32.27	-31.69	-32.48	-31.99	-28.35
Tr2 av [°C] =	-32.20	-32.24	-31.84	-31.66	-31.30	-32.54	-31.92	-28.34
Pass 3								
Tr3-1 [°C] =	-29.95	-30.04	-30.76	-31.63	-31.13	-32.41	-31.88	-28.16
Tr3-2 [°C] =	-26.68	-26.62	-26.45	-26.39	-25.84	-31.1	-31.4	-26.81
Tr3-3 [°C] =	-30.08	-29.78	-28.04	-26.67	-25.09	-31.45	-31.78	-27.27
Tr3 av [°C] =	-28.90	-28.81	-28.42	-28.23	-27.35	-31.65	-31.69	-27.41
Evap Outlet								
Tro-1 [°C] =	-23.80	-23.85	-23.97	-24.29	-23.83	-27.73	-30.64	-23.61
Tro-2 [°C] =	-24.23	-24.18	-24.16	-24.31	-23.8	-27.82	-30.25	-23.76
Tro-3 [°C] =	-24.58	-24.42	-24.28	-24.35	-23.78	-28.84	-30.75	-24.89
Tro av [°C] =	-24.20	-24.15	-24.14	-24.32	-23.80	-28.13	-30.55	-24.09
Cold Fluid In								
Trex [°C] =	-23.44	-23.39	-23.3	-23.44	-22.93	-27.05	-30.55	-23.27
Trhx-4 [°C] =	-19.42	-19.32	-19.23	-19.39	-18.86	-23.45	-30.82	-20.31
Cold Fluid Out								
Trhx-3 [°C] =	-7.72	-7.72	-7.68	-7.85	-7.18	-9.33	-19.32	-7.21

DATA	072396.a	072396.b	072396.c	072396.d	072396.e	81296.1	81496.1	82696.1
Case Outlet								
Trout [°C] =	-5.65	-5.61	-5.58	-5.71	-5.15	-7.52	-17.65	-5.54
Case Delivered								
Tad-1 [°C] =	-29.61	-29.64	-29.71	-29.74	-29.44	-29.75	-29.24	-25.63
Tad-2 [°C] =	-29.68	-29.64	-29.6	-29.81	-29.48	-29.99	-29.48	-25.64
Tad-3 [°C] =	-29.87	-26.98	-27.53	-29.47	-29.16	-29.38	-28.62	-25.3
Tad-4 [°C] =	-27.68	-24.44	-24.25	-23.91	-23.48	-27.54	-26.67	-22.83
Tad av [°C] =	-29.21	-27.68	-27.77	-28.23	-27.89	-29.17	-28.50	-24.85
Case Center								
Tac-1 [°C] =	24.58	24.64	24.59	24.63	25.48	25.3	25.08	25.82
Tac-2 [°C] =	-21.98	-22.17	-21.88	-21.69	-21.5	-22.15	-21.66	-18.24
Tac-3 [°C] =	-31.24	-31.19	-31.2	-31.26	-31.05	-30.67	-30.46	-27.22
Case Returned								
Tar-1 [°C] =	-21.80	-21.66	-22.07	-21.33	-21.2	-20.45	-19.33	-19.52
Tar-2 [°C] =	-22.54	-21.9	-21.88	-21.86	-21.79	-22.01	-21.15	-19.08
Tar-3 [°C] =	-23.01	-22.88	-22.86	-22.76	-22.16	-22.98	-22.22	-18.29
Tar-4 [°C] =	-20.31	-20.81	-20.68	-20.47	-19.91	-21.62	-19.64	-15.43
Tar a v [°C] =	-21.92	-21.81	-21.87	-21.61	-21.27	-21.77	-20.59	-18.08

CALCULATION	072396.a	072396.b	072396.c	072396.d	072396.e	81296.1	81496.1	82696.1
defrt time [min] =	20.54	20.94	20.95	20.76	20.41	16.51	21.08	20.41
Rel Hum [%] =	51.23	58.86	74.58	85.19	61.1	53.61	57.04	58.05
Display Case								
h.trin [kJ/kg]=	247.60	247.6	247.2	246.9	247.9	249.4	244.76	246.81
h.trout[kJ/kg]=	370.70	370.5	370.5	370.4	370.9	368.9	360.53	369.99
Qrt [kW] =	0.8654	0.8578	0.8545	0.8484	0.8499	0.8891	0.8984	0.8142
Evaporator								
h.rei [kJ/kg] =	213.30	213.3	213.1	212.7	213.7	213.53	196.63	212.68
h.reo [kJ/kg] =	355.40	355	355	355.4	355.8	356.2	350.02	353.29
Qevap [kW]=	0.9990	0.9891	0.9834	0.9803	0.9819	1.0615	1.1903	0.9294
Suction HX								
h.trhx-1 [kJ/kg] =	237.71	237.61	237.29	237.02	238.19	239.95	236.34	237.85
h.trhx-2 [kJ/kg] =	213.15	213.09	212.87	212.51	213.53	213.36	196.27	212.49
Qliq [kW] =	-0.1727	-0.1711	-0.1692	-0.1684	-0.1704	-0.1978	-0.3109	-0.1676
h.trhx-3 [kJ/kg] =	369.79	369.8	369.85	369.72	370.25	368.44	360.4	369.66
h.trhx-4 [kJ/kg] =	360.47	360.56	360.65	360.53	360.93	356.27	351.5	359.23
Qvap [kW] =	0.0655	0.0645	0.0638	0.0631	0.0644	0.0905	0.0691	0.0689
Saturation								
Tsat,l [°C] =	-35.29	-35.43	-35.57	-35.65	-35.51	-34.8	-33.87	-30.46
Tsat,v [°C] =	-34.67	-34.81	-34.95	-35.02	-34.88	-34.19	-33.25	-29.85
hsat,l [kJ/kg] =	152.20	151.75	151.57	151.47	151.65	152.51	154.11	159.05
hsat,v [kJ/kg] =	346.96	348.64	348.55	348.5	348.59	347.28	347.92	350.05
Tglide [°C] =	0.62	0.62	0.62	0.63	0.63	0.61	0.62	0.61
Tsupheat [°C] =	10.47	10.66	10.81	10.70	11.08	6.06	2.70	5.76
quality [-] =	0.314	0.313	0.312	0.311	0.315	0.313	0.219	0.281
Air Temp								
d Tevap [°C] =	9.26	9.02	9.32	9.57	9.55	8.52	8.80	8.98
inlet[°C] =	0.06	0.36	0.01	0.09	0.24	0.38	1.08	0.16
outlet [°C] =	-2.03	-3.52	-3.43	-3.03	-3.16	-1.51	-1.96	-2.37

DATA	82896.1	090596.a	090596.b	90996.1	91496.1	91796.1	92396.1	93096.1	111996
mdot [g/s] =	6.9	6.95	6.91	6.86	6.37	6.02	5.52	4.48	8.09
Pressures									
Prin [kPa] =	1917.06	1823.81	1818.02	1815.79	1820.69	1830.73	1848.14	1887.01	1774.25
Prout [kPa] =	202.55	193.43	191.54	191.54	235.64	243.91	317.34	360.54	150.26
Power Usage									
W1 [kPa] =	288.06	308.37	305.41	306.65	310.03	309.71	310.1	306.97	309.46
W2 [kPa] =	0.21	0.01	0.1	0.14	-0.09	-0.13	-0.14	0.15	-0.14
General Temp									
Tref [°C] =	26.21	26.22	25.79	25.72	24.45	24.21	24.59	24.9	23.84
Tdb [°C] =	25.15	25.7	25.46	25.24	24.27	24.08	24.86	25.31	24.06
Twb [°C] =	19.24	19.66	19.85	19.14	16.46	17.24	18.44	17.73	17.04
Case Inlet									
Trin [°C] =	30.1	29.2	28.87	28.67	28.28	28.07	27.66	27.39	26.26
Hot Fluid In									
Trhx-1 [°C] =	25.09	24.17	23.84	23.57	23.26	23.07	23.17	23.02	21.71
Hot Fluid Out									
Trhx-2 [°C] =	8.9	7.65	7.23	7.17	7.15	9.21	11	13.29	0.56
Evap Inlet									
Tri-1 [°C] =	-29.7	-30.94	-31.21	-31.14	-26.22	-25.25	-18.46	-14.96	-36.71
Tri-2 [°C] =	-29.76	-31	-31.28	-31.2	-26.3	-25.32	-18.55	-15.02	-36.63
Tri-3 [°C] =	-29.38	-30.69	-30.97	-30.91	-26.07	-25.02	-18.36	-14.78	-36.39
Tri av [°C] =	-29.61	-30.88	-31.15	-31.08	-26.20	-25.20	-18.46	-14.92	-36.58
Pass 1									
Tr1-1 [°C] =	-29.4	-30.68	-39.95	-30.86	-25.97	-24.87	-18.08	-13.76	-35.65
Tr1-2 [°C] =	-29.5	-30.67	-30.93	-30.85	-25.96	-24.85	-17.95	-9.1	-35.95
Tr1-3 [°C] =	-29.34	-30.6	-30.88	-30.77	-25.91	-24.76	-17.97	-11.9	-35.88
Tri av [°C] =	-29.41	-30.65	-33.92	-30.83	-25.95	-24.83	-18.00	-11.59	-35.83
Pass 2									
Tr2-1 [°C] =	-28.66	-30.16	-30.45	-30.36	-25.53	-24.26	-17.54	-6.16	-33.79
Tr2-2 [°C] =	-28.97	-30.28	-30.54	-30.46	-25.56	-23.35	-14.56	-5.74	-34.77
Tr2-3 [°C] =	-28.86	-30.14	-30.46	-30.29	-25.55	-23.61	-17.31	-5.44	-34.76
Tr2 av [°C] =	-28.83	-30.19	-30.48	-30.37	-25.55	-23.74	-16.47	-5.78	-34.44
Pass 3									
Tr3-1 [°C] =	-28.67	-29.96	-30.28	-30.16	-25.35	-23.15	-16.93	-3.52	-32.1
Tr3-2 [°C] =	-27.03	-29.06	-29.36	-29.19	-24.06	-19.14	-13.15	-3.73	-33.05
Tr3-3 [°C] =	-27.97	-29.27	-29.04	-29.4	-24.78	-18.71	-14.53	-3.4	-33.48
Tr3 av [°C] =	-27.89	-29.43	-29.56	-29.58	-24.73	-20.33	-14.87	-3.55	-32.88
Evap Outlet									
Tro-1 [°C] =	-23.61	-26.09	-26.76	-26.17	-22.26	-17.01	-11.37	-2.66	-32.04
Tro-2 [°C] =	-24.02	-26.2	-26.67	-26.3	-22.29	-17.34	-11.59	-3.05	-32.32
Tro-3 [°C] =	-25.02	-27.32	-27.82	-27.4	-23.33	-17.42	-11.63	-3.35	-33.41
Tro av [°C] =	-24.22	-26.54	-27.08	-26.62	-22.63	-17.26	-11.53	-3.02	-32.59
Cold Fluid In									
Trex [°C] =	-23.4	-25.56	-26	-25.64	-22.09	-16.55	-10.87	-2.8	-33.28
Trhx-4 [°C] =	-19.89	-22.36	-22.83	-22.32	-19.43	-12.88	-7.6	0.28	-32.87
Cold Fluid Out									
Trhx-3 [°C] =	-7.4	-9	-9.26	-9.28	-6.97	-3.32	0.45	5.85	-19.07

DATA	82896.1	090596.a	090596.b	90996.1	91496.1	91796.1	92396.1	93096.1	111996
Case Outlet									
Trout [°C] =	-5.72	-7.27	-7.52	-7.51	-5.71	-1.92	1.69	7.04	-19.68
Case Delivered									
Tad-1 [°C] =	-26.28	-27.59	-27.85	-27.81	-23.5	-21.68	-15.33	-8.9	-30.57
Tad-2 [°C] =	-26.41	-27.7	-27.89	-27.85	-23.41	-21.48	-15.09	-6.75	-30.58
Tad-3 [°C] =	-26.11	-27.25	-27.47	-27.52	-23.09	-21.37	-13.79	-7.05	-29.28
Tad-4 [°C] =	-23.94	-24.8	-25.02	-25.03	-20.21	-17.36	-13.97	-4.02	-28.78
Tad av [°C] =	-25.69	-26.84	-27.06	-27.05	-22.55	-20.47	-14.55	-6.68	-29.80
Case Center									
Tac-1 [°C] =	25.4	25.41	25.18	24.97	24.27	24.22	25.27	26.16	23.61
Tac-2 [°C] =	-19.76	-20.53	-20.66	-20.96	-17.18	-15.31	-9.11	-1.22	-23.21
Tac-3 [°C] =	-27.46	-28.76	-28.95	-28.94	-24.23	-22.43	-15.9	-7.53	-31.98
Case Returned									
Tar-1 [°C] =	-19.96	-20.52	-20.35	-20.83	-17.35	-15.94	-9.71	-2.75	-21.17
Tar-2 [°C] =	-20.19	-19.97	-20.11	-20.99	-18.28	-16.5	-10.44	-2.36	-22.52
Tar-3 [°C] =	-20.3	-21.22	-21.38	-21.55	-18.16	-16.49	-10.1	-2.28	-24.65
Tar-4 [°C] =	-18.39	-19.13	-19.71	-19.54	-16.19	-14.14	-8.2	0.03	-21.9
Tar a v [°C] =	-19.71	-20.21	-20.39	-20.73	-17.50	-15.77	-9.61	-1.84	-22.56

CALCULATION	82896.1	090596.a	090596.b	90996.1	91496.1	91796.1	92396.1	93096.1	111996
defrost time [min] =	19.55	17.51	18.29	18.42	19.31	17.51	12.17	11.75	16.43
Relative Hum [%] =	57.7	57.38	59.9	56.58	44.91	50.71	54.19	47.54	49.55
Display Case									
h.trin [kJ/kg]=	246.37	244.84	244.28	243.82	243.28	242.92	242.26	241.82	239.94
h.trout[kJ/kg]=	369.88	368.77	368.6	368.62	369.4	372.45	374.4	378.4	362.84
Qrt [kW] =	0.8522	0.8613	0.8591	0.8561	0.8034	0.7798	0.7294	0.6119	0.9943
Evaporator									
h.rei [kJ/kg] =	212.95	211.08	210.45	210.36	210.33	213.94	216	219.54	200.78
h.reo [kJ/kg] =	354.92	353.2	352.81	353.2	355.6	359.76	363.31	369.54	349.18
Qevap [kW]=	0.9796	0.9877	0.9837	0.9799	0.9254	0.8778	0.8132	0.6720	1.2006
Suction HX									
h.trhx-1 [kJ/kg] =	237.48	236.01	235.48	235.05	234.56	234.26	234.42	234.18	232.12
h.trhx-2 [kJ/kg] =	212.75	210.93	210.32	210.23	210.2	213.21	215.84	219.25	200.73
Qliq [kW] =	-0.1706	-0.1743	-0.1739	-0.1703	-0.1552	-0.1267	-0.1026	-0.0669	-0.2539
h.trhx-3 [kJ/kg] =	369.57	368.41	368.23	368.21	369.43	372.28	374.29	378.13	361.02
h.trhx-4 [kJ/kg] =	359.62	357.82	357.49	357.88	359.5	364.56	367.72	361.02	350.37
Qvap [kW] =	0.0687	0.0736	0.0742	0.0709	0.0633	0.0465	0.0363	0.0767	0.0862
Saturation									
Tsat,l [°C] =	-30.95	-32.09	-32.34	-32.34	-27.12	-26.23	-19.22	-15.67	-38.17
Tsat,v [°C] =	-30.34	-31.48	-31.72	-31.72	-26.52	-25.63	-18.64	-15.11	-37.55
hsat,l [kJ/kg] =	157.89	156.36	155.8	157.28	163.63	164.76	173.77	179.74	148.27
hsat,v [kJ/kg] =	349.71	349.03	350.64	349.49	352.16	352.69	356.95	359.76	345.19
Tglide [°C] =	0.61	0.61	0.62	0.62	0.60	0.60	0.58	0.56	0.62
Tsupheat [°C] =	6.12	4.94	4.64	5.10	3.89	8.37	7.11	12.09	4.96
quality [-] =	0.287	0.284	0.280	0.276	0.248	0.262	0.231	0.221	0.267
Air Temp									
d Tevap [°C] =	7.70	8.23	8.29	7.98	7.05	7.12	6.79	6.31	8.77
inlet[°C] =	0.05	0.32	0.27	0.23	-0.32	-0.46	-0.50	-0.62	0.65
outlet [°C] =	-1.78	-1.93	-1.89	-1.89	-1.68	-1.96	-1.36	-0.85	-2.18

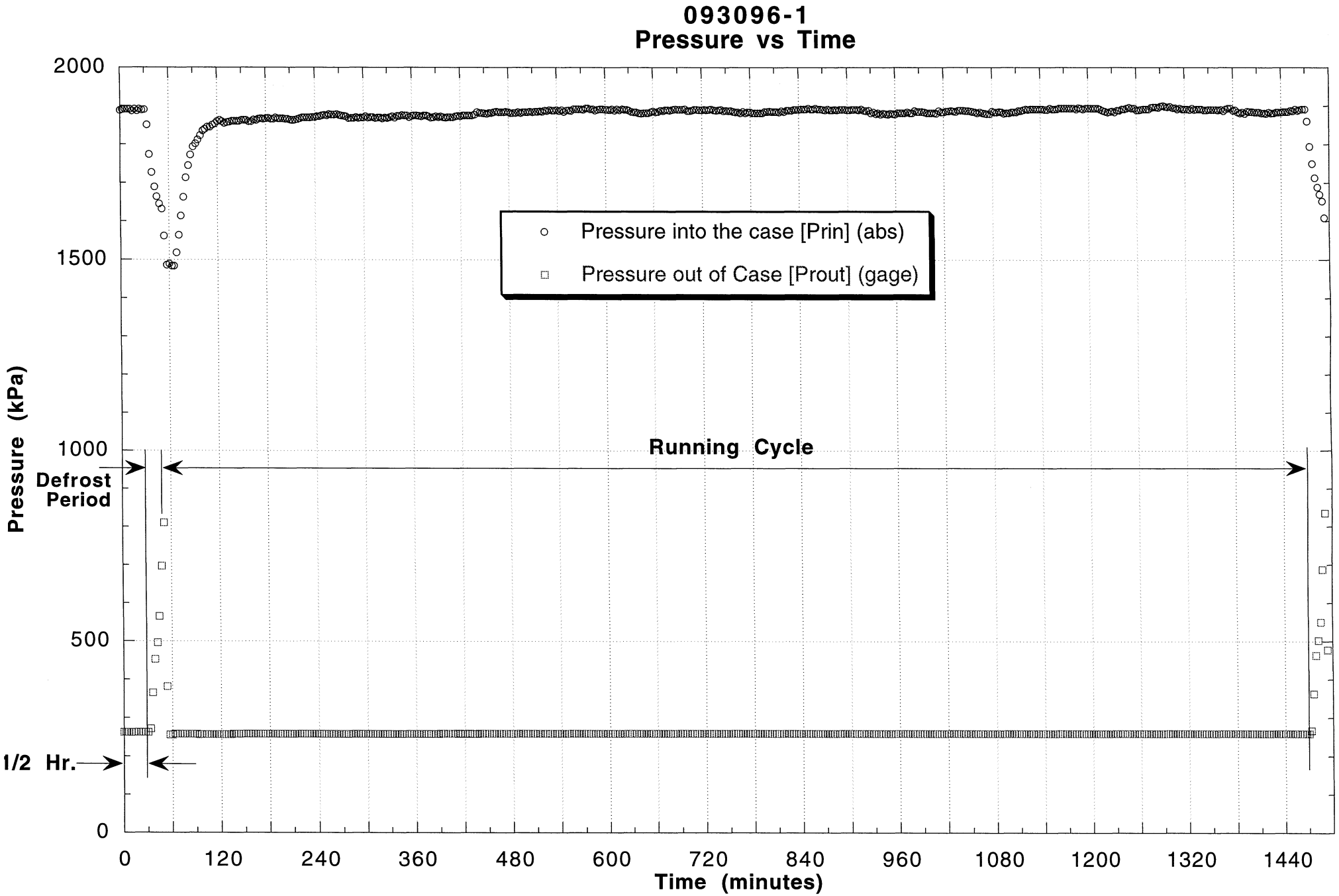


Figure A1-1. 24 Hour Period of a Typical Test Level (Pressure vs Time)

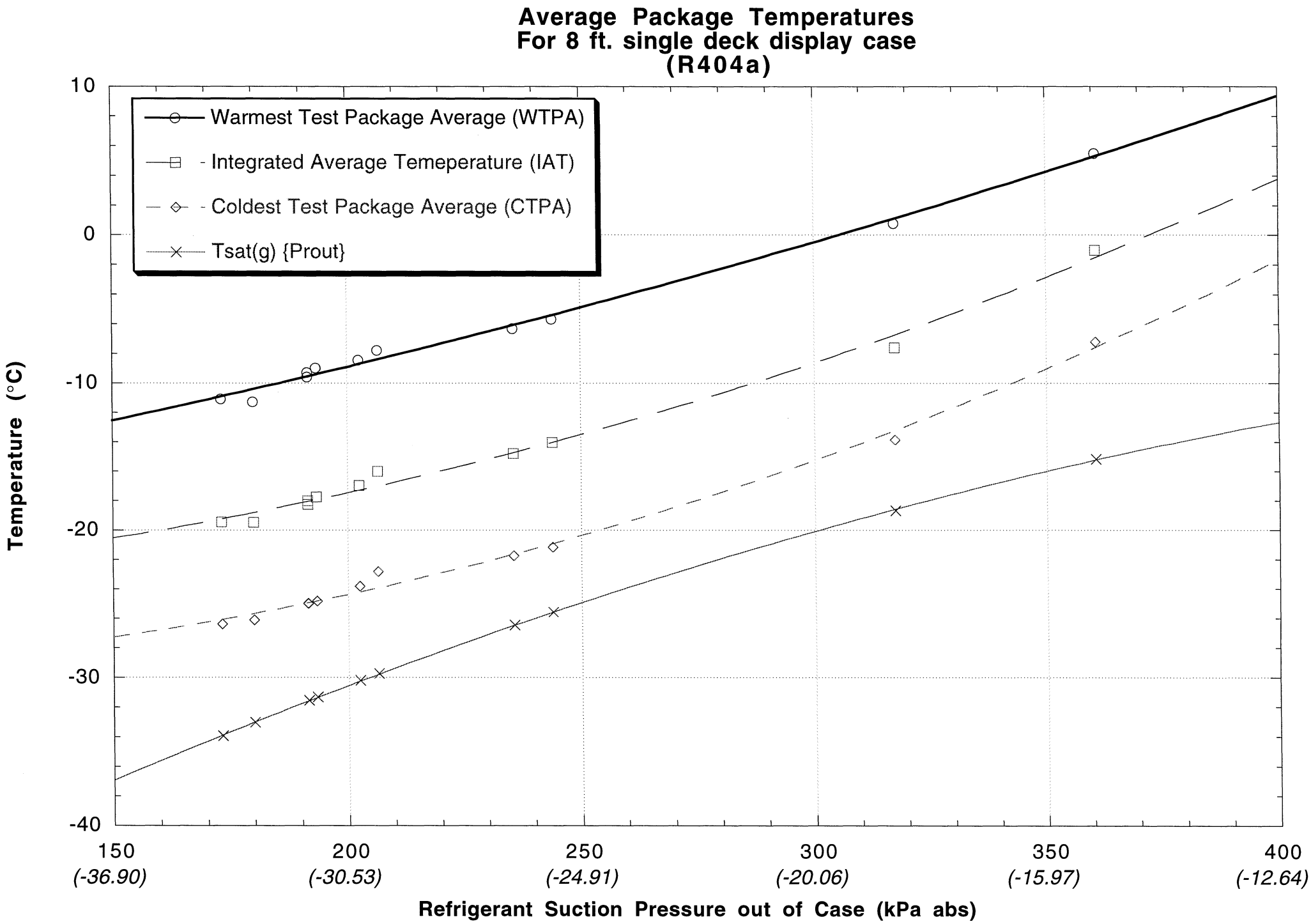


Figure A1-2. Package Temperatures in Baseline Test according to ASHRAE Standard 72

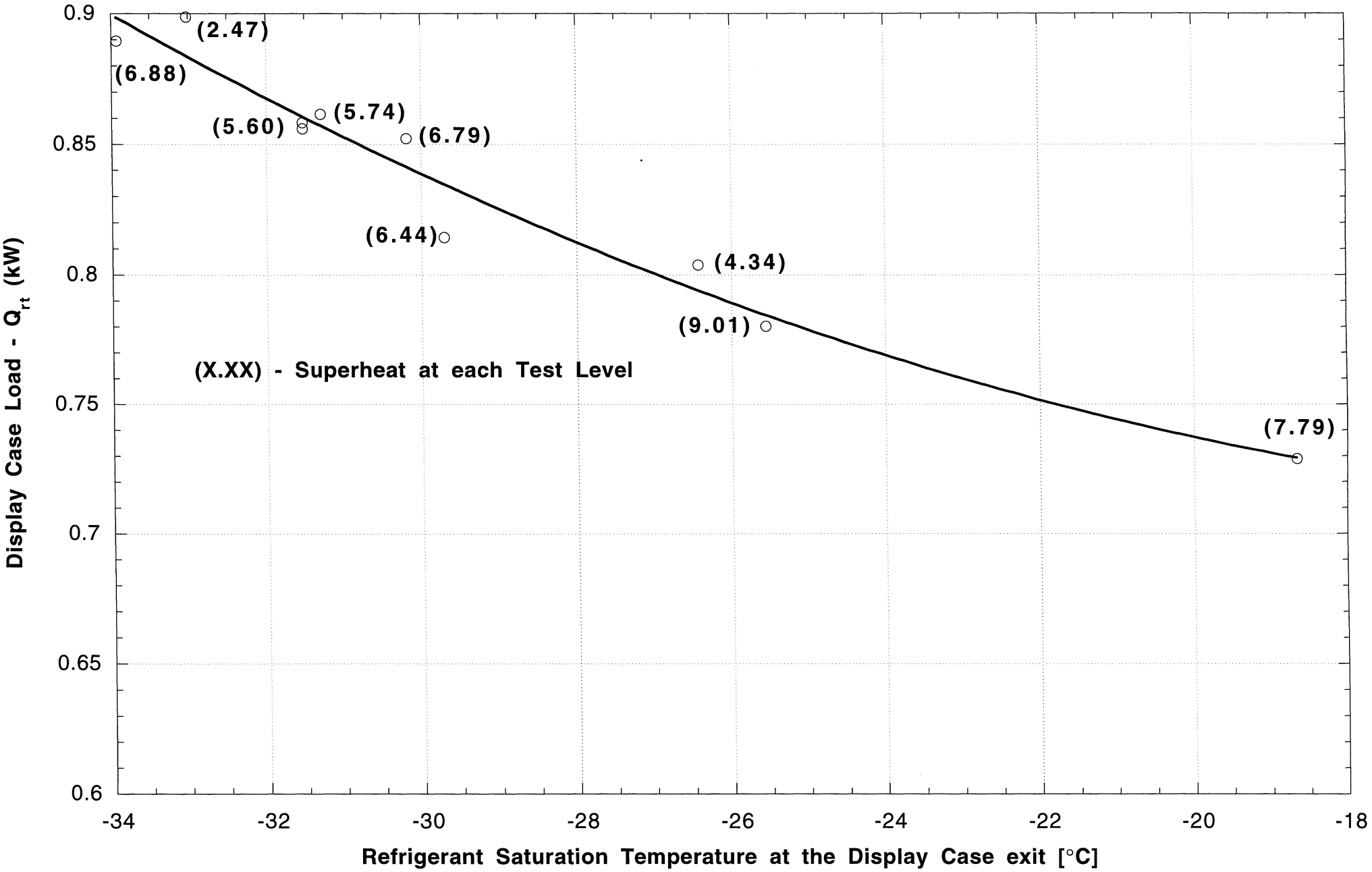


Figure A1-3. Capacity needed to Refrigerate 8ft. single deck display case for each Baseline Test Level

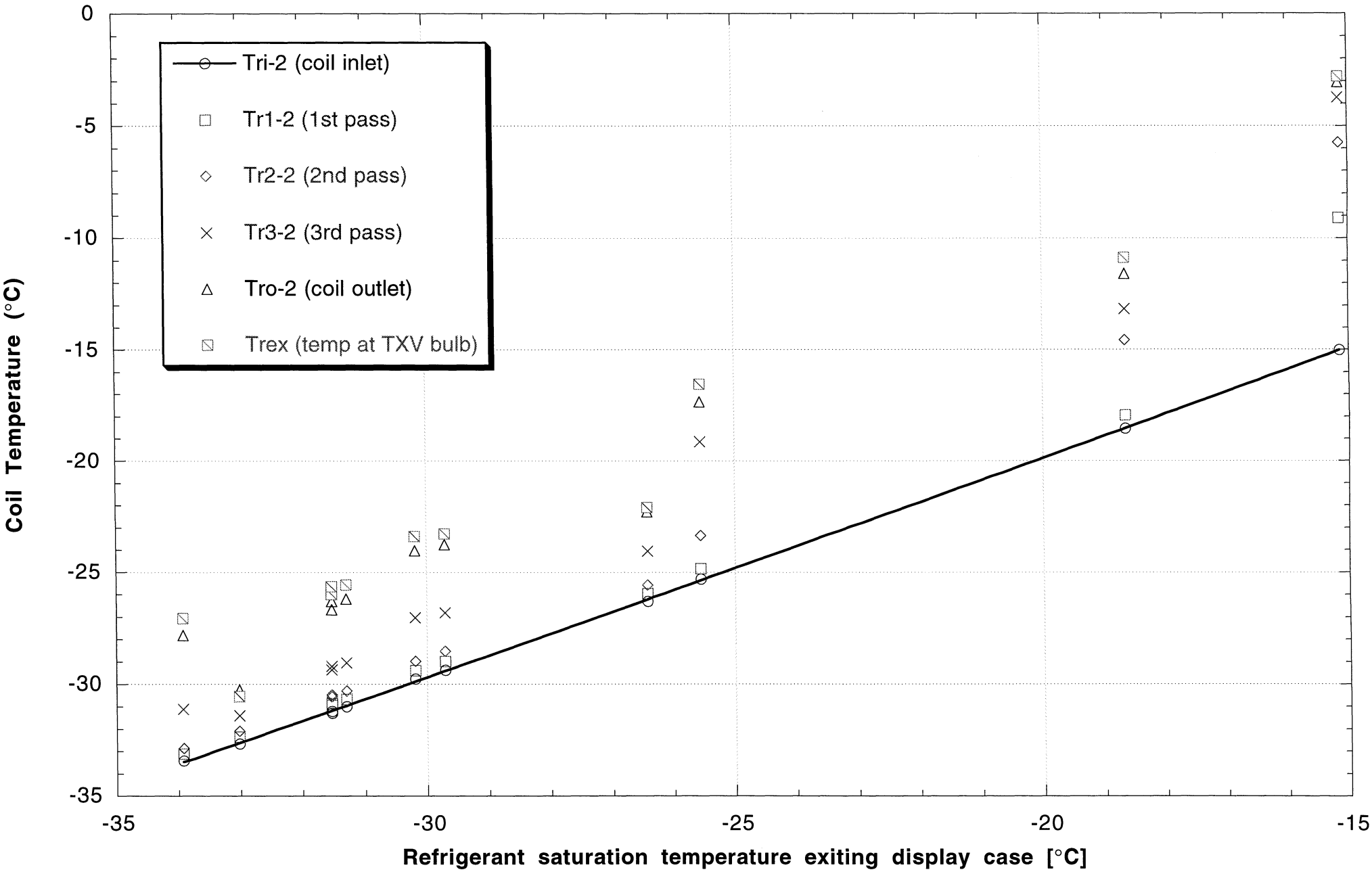


Figure A1-4 Evaporator Performance vs Saturation Temperature in Baseline Test

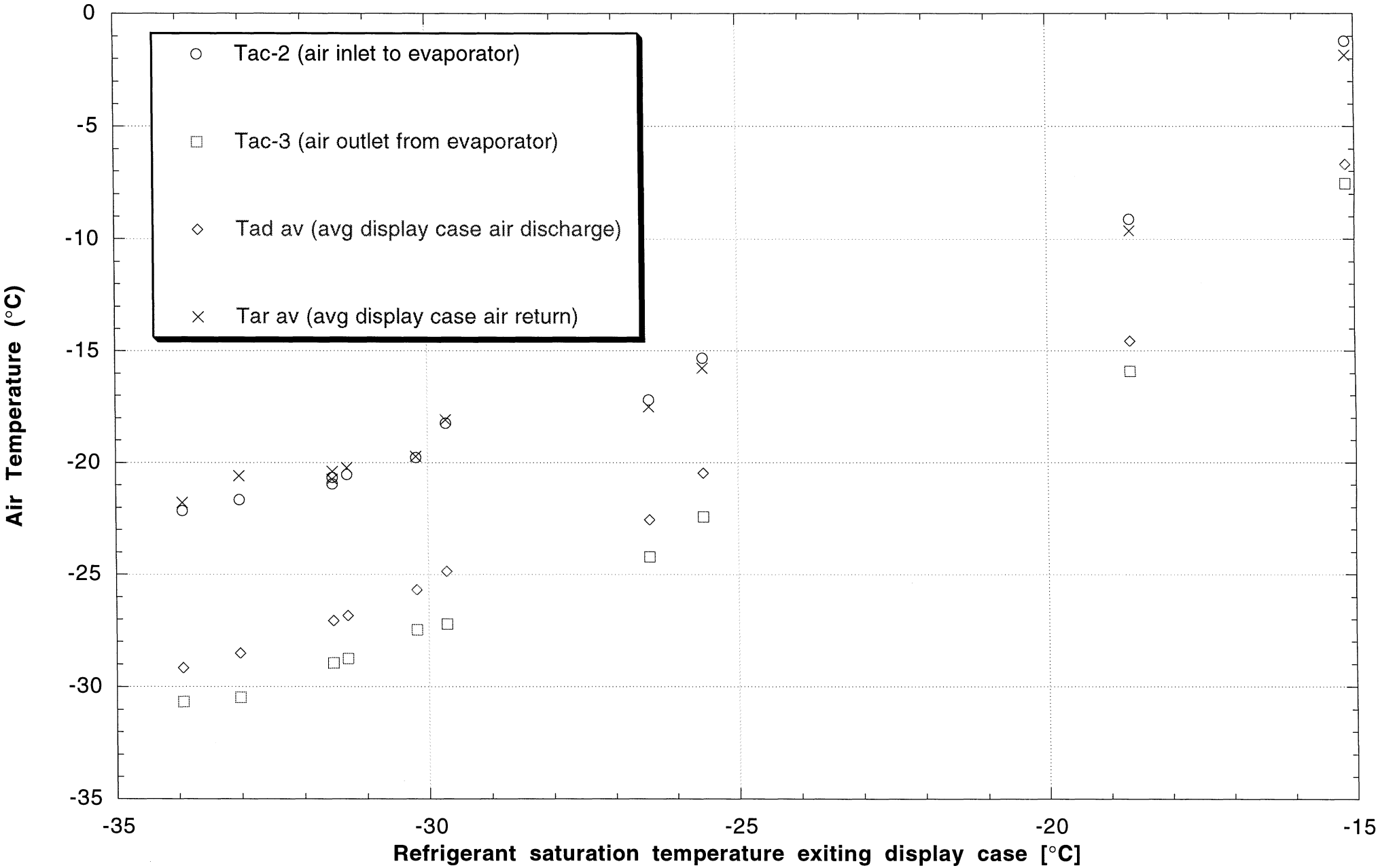


Figure A1-5. Air temperatures for 8 ft single deck display case in baseline test

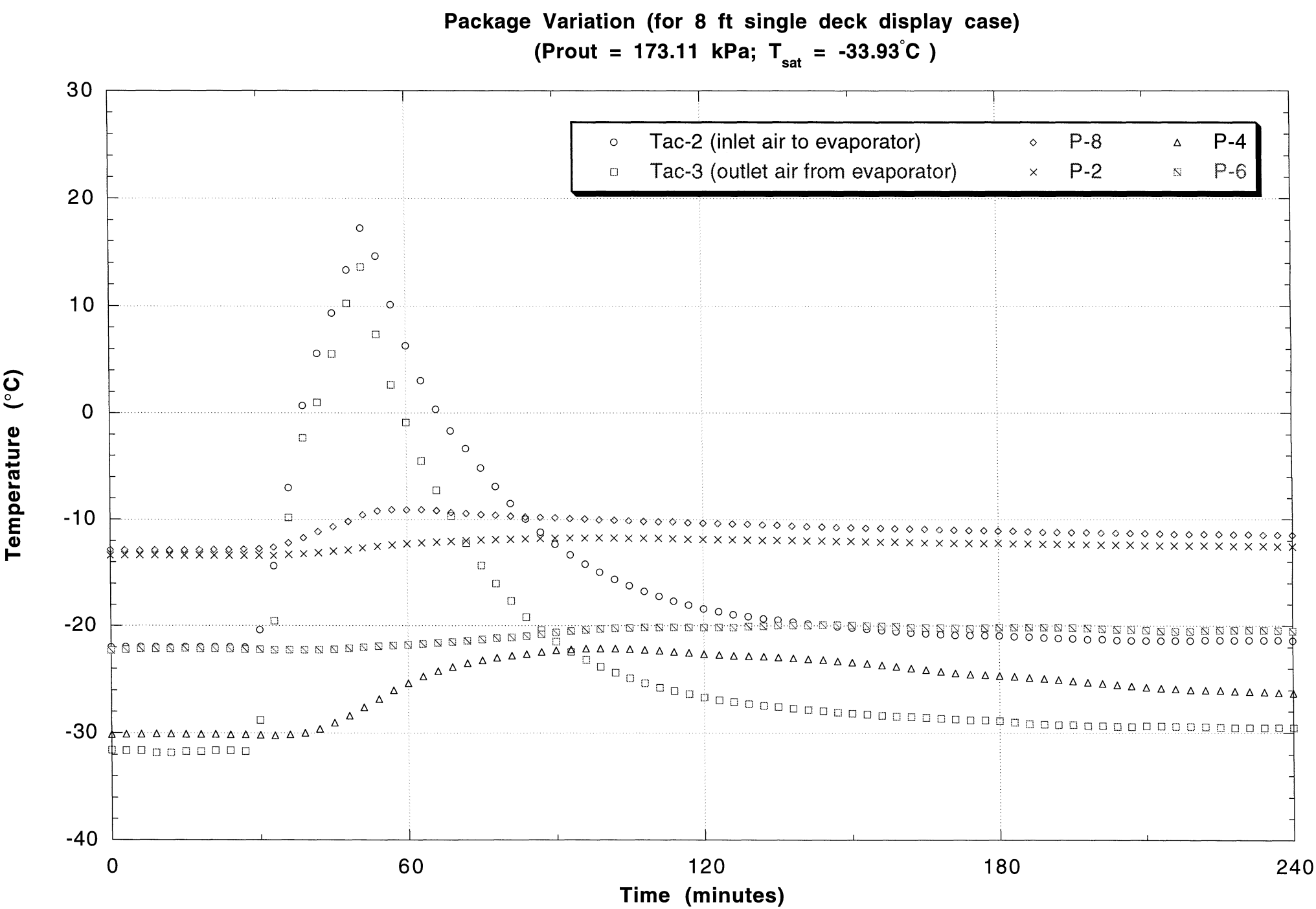


Figure A1-6. Response of package temperatures (coldest P-4 and P-6; hottest P-8 and P-2) and air temperatures at the inlet and outle of evaporator to defrost

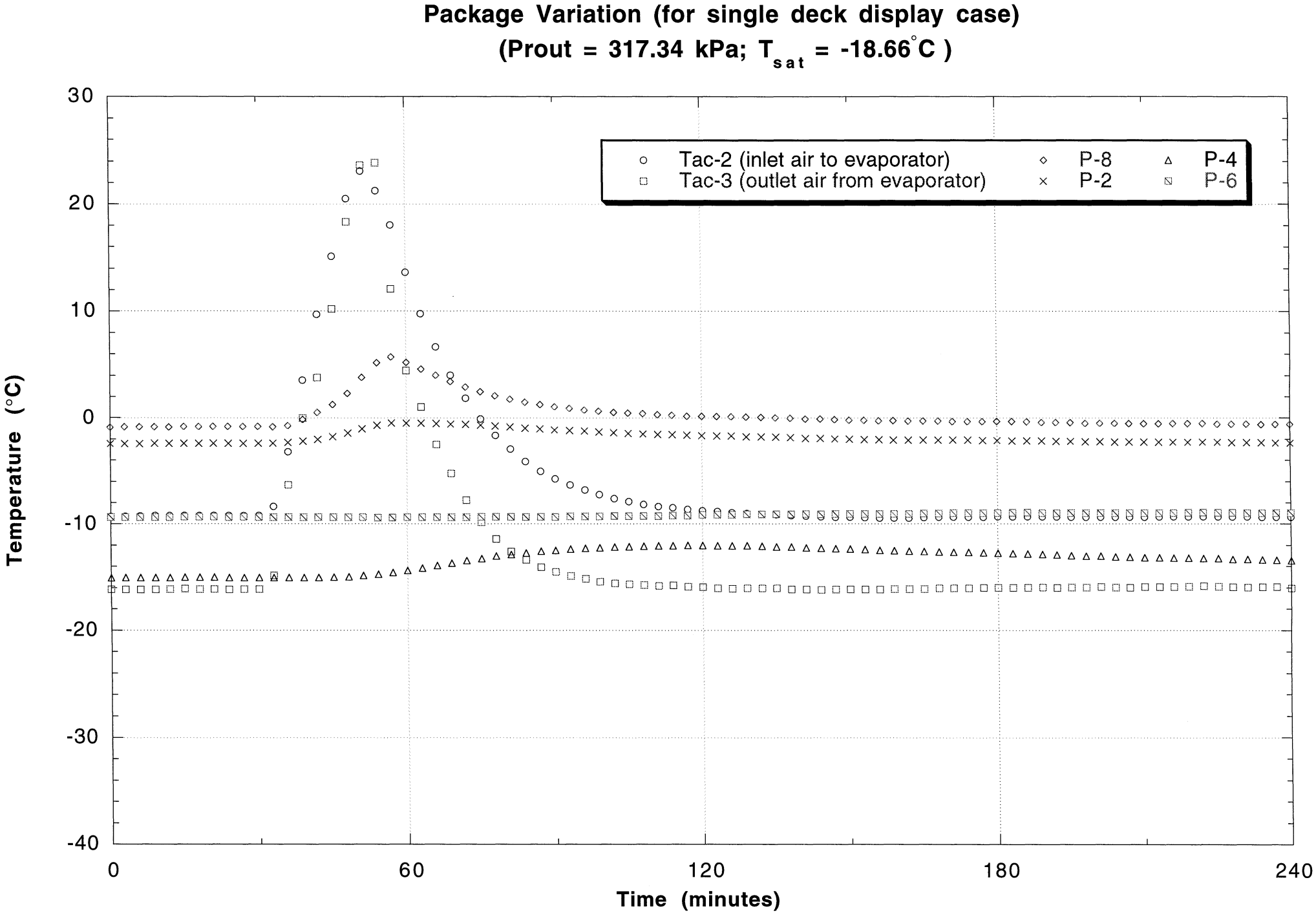


Figure A1-7. Response of package temperatures (coldest P-4 and P-6; hottest P-8 and P-2) and air temperatures at the inlet and outlet of evaporator to defrost

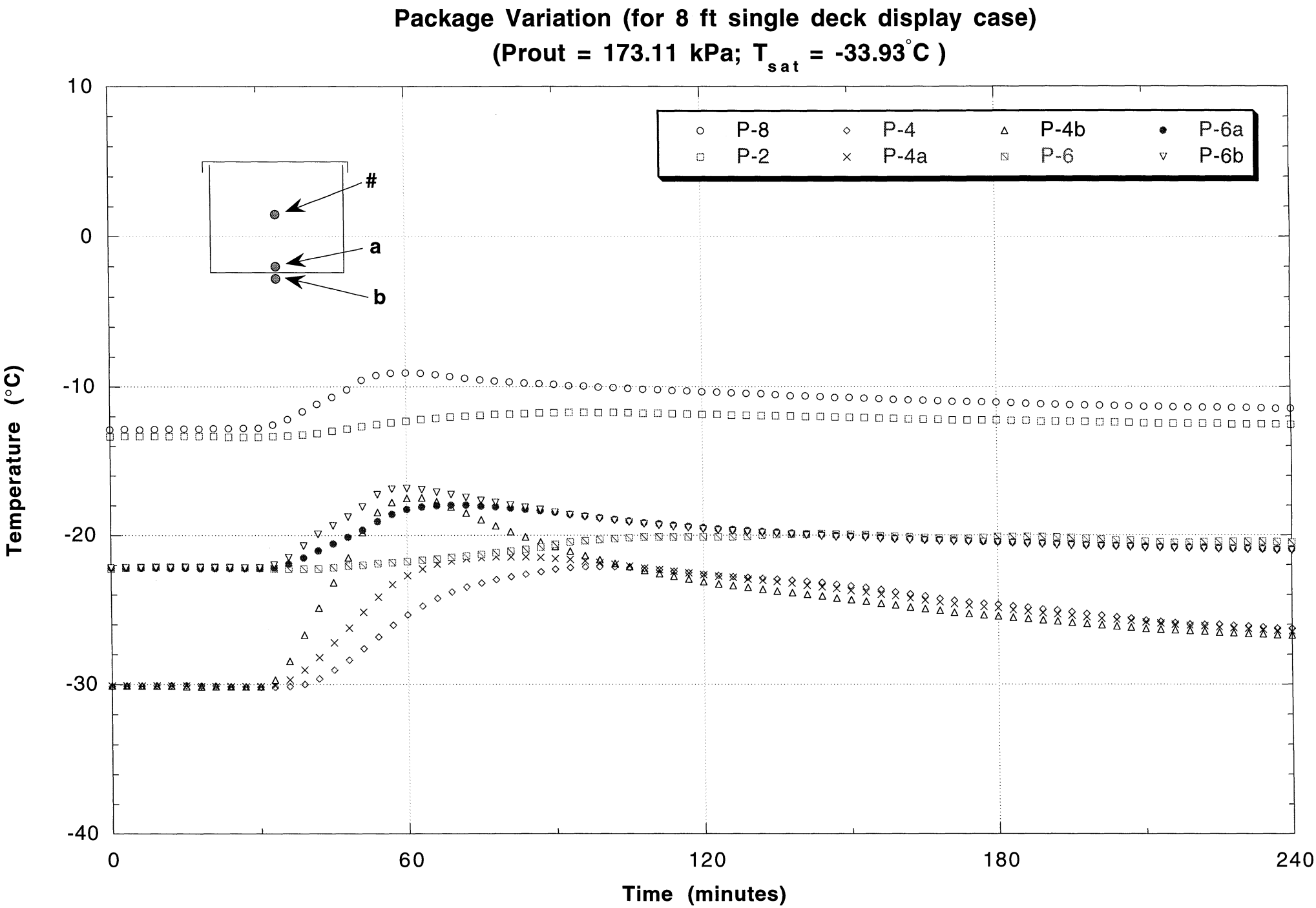


Figure A1-8. Variation in lowest package temperature (center 4; bottom 4a; outside 4b) at low test level

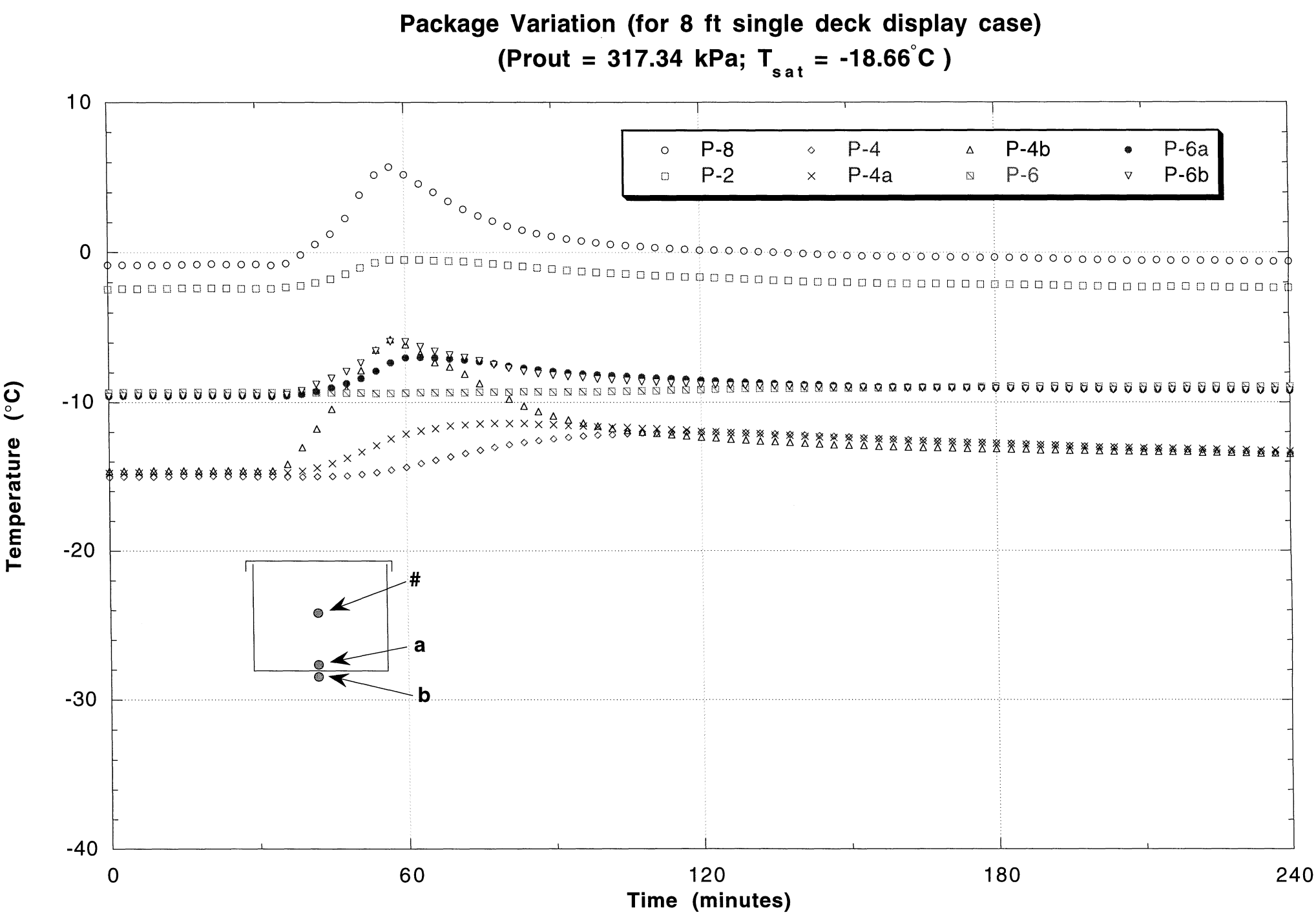


Figure A1-9. Variation in lowest package temperature (center 4; bottom 4a; outside 4b) at medium test level

Air Velocities

Velocities were taken before and after defrost to see the difference in air flow as frost is removed during defrost. Samples of the air stream was taken at various points from the discharge and the return with an hot wire anemometer. Graphs of these samples can be seen below.

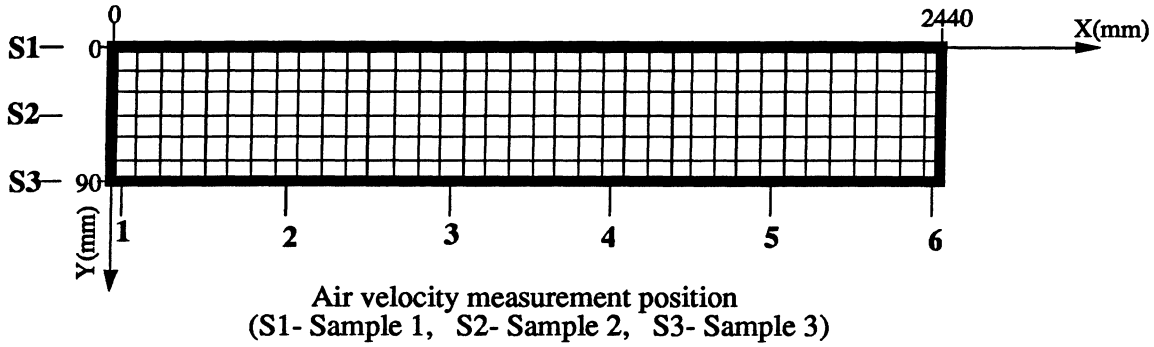


Figure A1-10. Front view of air discharge window with position of sample measurement

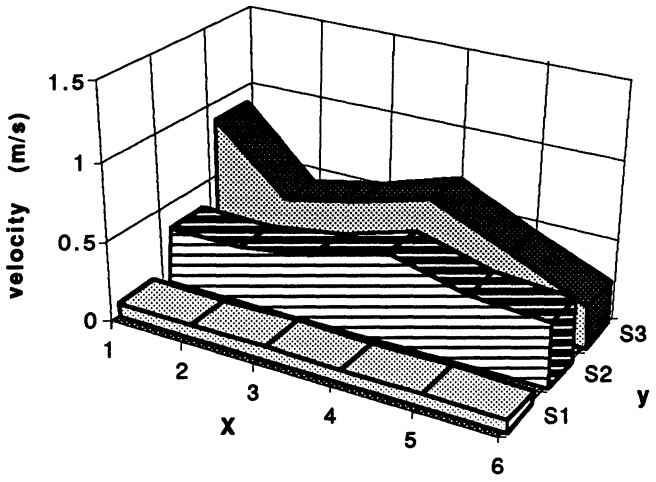


Figure A1-11. Typical air velocity distribution at air discharge window before defrost

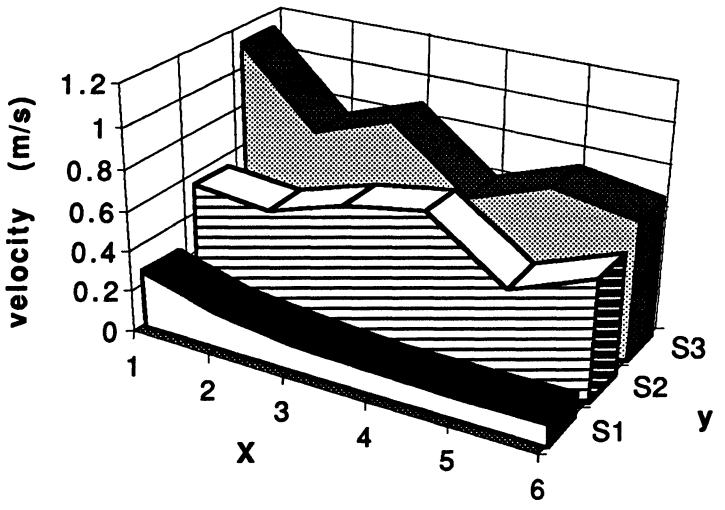


Figure A1-12. Typical air velocity distribution at air discharge window after defrost

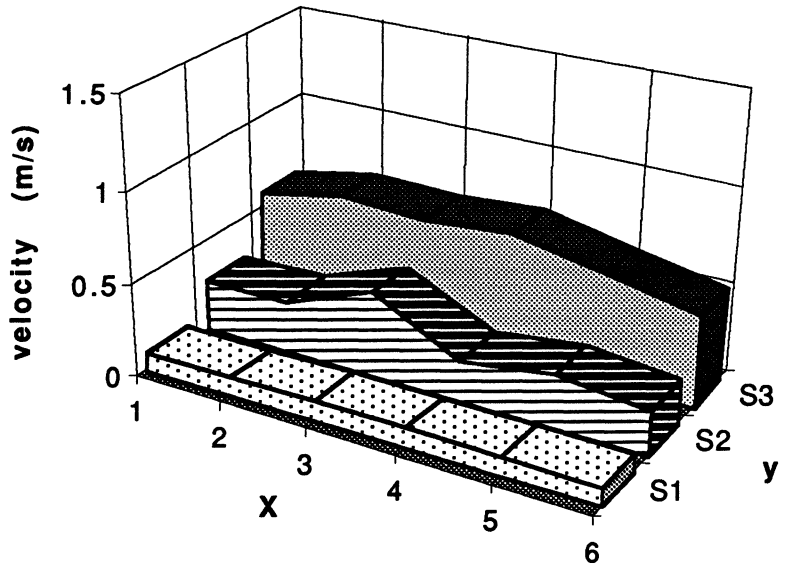


Figure A1-13. Typical air velocity distribution at air return window before defrost

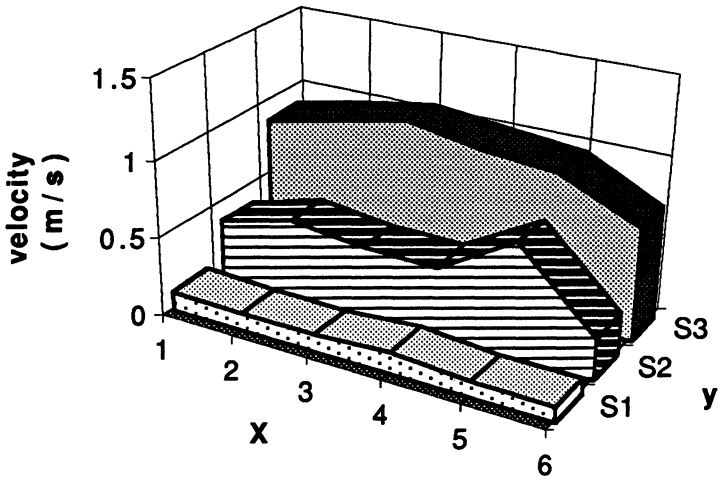


Figure A1-14. Typical air velocity distribution at air return window after defrost

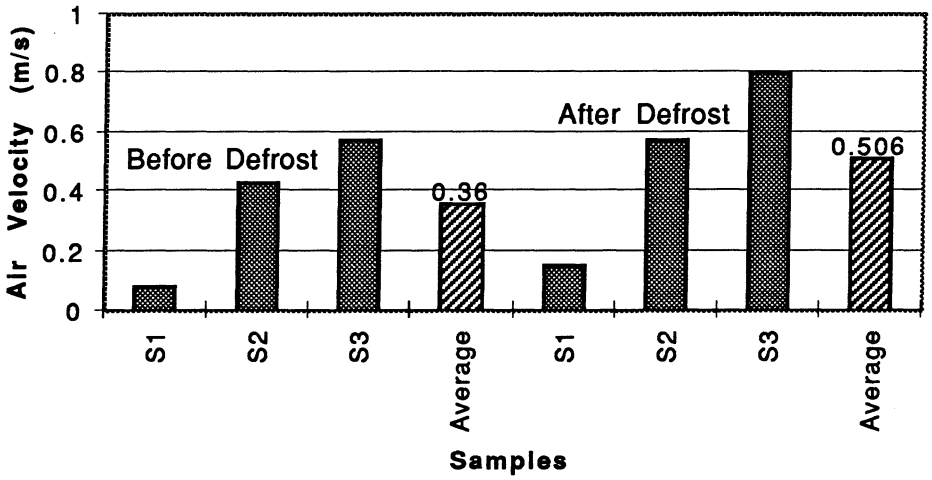


Figure A1-15. Comparison of average velocity before and after defrost for discharge air

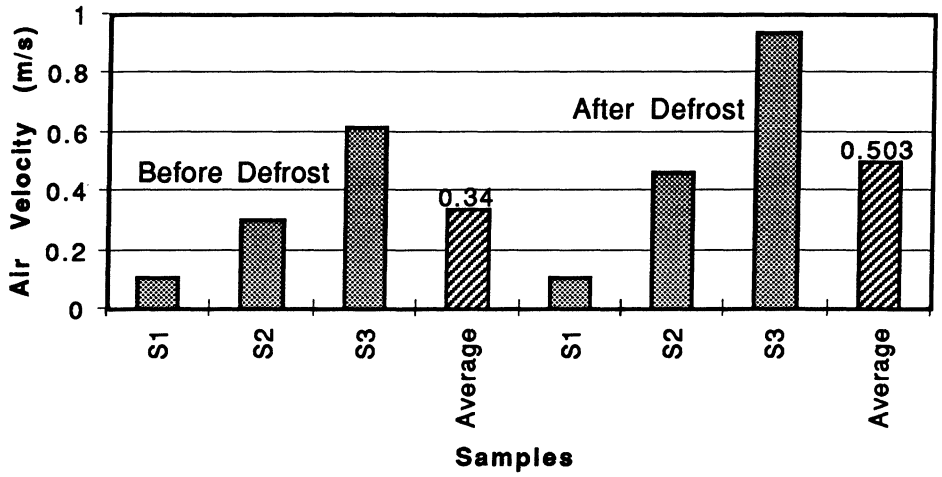


Figure A1-16. Comparison of average velocity before and after defrost for return air

The sample shows that the average velocity at the discharge seems to be slightly higher than the return.

Average values of data during last 3/4's of running cycle (SI)

DATE:	072396-a
MINUTES:	

MASS FLOW RATE	
mdot [g/s] =	7.03

PRESSURES	(Absolute)
Prin [kPa] =	1879.77
Prout [kPa] =	169.67

POWER USAGE	
W1 [W] =	305.76
W2 [W] =	0.03

GENERAL TEMPERATURES	
Tref [°C] =	25.33
Tdb [°C] =	24.73
Twb [°C] =	17.86

SAT TEMP (Prout)	
Tsat [°C] =	-34.40

SUPERHEAT	
[°C] =	10.96

CASE INLET	
Trin [°C] =	30.80

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	25.23
HOT FLUID OUT	
Trhx-2 [°C] =	9.17

EVAPORATOR INLET	
Tri-1 [°C] =	-33.94
Tri-2 [°C] =	-34.00
Tri-3 [°C] =	-33.72
Tri av [°C] =	-33.89
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-33.37
Tr1-2 [°C] =	-33.55
Tr1-3 [°C] =	-33.33
Tri av [°C] =	-33.42
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-32.56
Tr2-2 [°C] =	-31.37
Tr2-3 [°C] =	-32.66
Tr2 av [°C] =	-32.20
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-29.95
Tr3-2 [°C] =	-26.68
Tr3-3 [°C] =	-30.08
Tr3 av [°C] =	-28.90
EVAPORATOR OUTLET	
Tro-1 [°C] =	-23.80
Tro-2 [°C] =	-24.23
Tro-3 [°C] =	-24.58
Tro av [°C] =	-24.20
XCHR: COLD FLUID IN	
Trex [°C] =	-23.44
Trhx-4 [°C] =	-19.42
COLD FLUID OUT	
Trhx-3 [°C] =	-7.72

CASE OUTLET	
Trout [°C] =	-5.65

PACKAGE TEMPERATURES	
P-1 [°C] =	-22.15
P-2 [°C] =	-13.09
P-3 [°C] =	-15.89
P-4 [°C] =	-29.37
P-5 [°C] =	-24.54
P-6 [°C] =	-21.68
P-7 [°C] =	-21.23
P-8 [°C] =	-12.43
P-9 [°C] =	-15.37
P-10 [°C] =	-27.95
P-11 [°C] =	-22.14
P-12 [°C] =	-20.10

CASE AIR: DELIVERED	
Tad-1 [°C] =	-29.61
Tad-2 [°C] =	-29.68
Tad-3 [°C] =	-29.87
Tad-4 [°C] =	-27.68
Tad av [°C] =	-29.21
CASE AIR: CENTER	
Tac-1 [°C] =	24.58
Tac-2 [°C] =	-21.98
Tac-3 [°C] =	-31.24

CASE AIR: RETURNED	
Tar-1 [°C] =	-21.80
Tar-2 [°C] =	-22.54
Tar-3 [°C] =	-23.01
Tar-4 [°C] =	-20.31
Tar a v [°C] =	-21.91

htrhx-1	238.27
Qliq	0.1755

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	370.7
hl [kJ/kg] =	247.6
Qrt [kW] =	0.8654

EVAPORATOR LOAD	
ho [kJ/kg] =	355.4
hi [kJ/kg] =	213.3
Qevap [kW] =	0.9989

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.2411
Qvap [kW] =	0.1076

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-28.86	-22.21	-20.65	-21.32	-13.29	-15.87	-30.98	-25.74	-21.97	-22.13	-13.45	-15.88
2	-27.12	-22.07	-20.51	-18.5	-9.03	-14.85	-26.39	-24.87	-21.72	-20.14	-12.41	-13.86
3	-21.77	-21.17	-18.58	-15.17	-8.87	-11.41	-21.01	-21.96	-19.15	-15.81	-10.79	-10.35
4	-22.3	-21.04	-18.19	-17.43	-10.11	-11.69	-21.96	-21.9	-18.83	-17.77	-11.35	-11.35
5	-23.58	-21.01	-18.24	-18.67	-10.73	-12.39	-23	-22.02	-19.21	-19.18	-11.85	-12.46
6	-24.72	-20.99	-18.37	-19.29	-11.02	-12.9	-25.23	-22.19	-19.72	-19.95	-12.11	-13.22
7	-25.63	-21.01	-18.57	-19.76	-11.33	-13.44	-26.57	-22.5	-20.28	-20.49	-12.33	-13.86
8	-26.22	-21.15	-18.82	-20.21	-11.54	-13.71	-27.14	-22.58	-20.47	-20.88	-12.44	-14.32
9	-24.64	-21.66	-19.96	-15.93	-7.47	-13.54	-23.03	-23.67	-21.25	-18.56	-11.52	-11.99
AV	-24.98	-21.37	-19.10	-18.48	-10.38	-13.31	-25.03	-23.05	-20.29	-19.43	-12.03	-13.03

Warmest Test Package	-10.38
Coldest Test Package	-25.03
Average Test Package	-18.37

Average values of data during last 3/4's of running cycle (SI)

DATE:	072396-b
MINUTES:	

MASS FLOW RATE	
mdot [g/s] =	6.98

PRESSURES	*(Absolute)*
Prin [kPa] =	1884.42
Prout [kPa] =	168.68

POWER USAGE	
W1 [W] =	307.12
W2 [W] =	0.03

GENERAL TEMPERATURES	
Tref [°C] =	25.37
Tdb [°C] =	24.79
Twb [°C] =	19.11

SAT TEMP (Prout)	
Tsat [°C] =	-34.54

SUPERHEAT	
[°C] =	11.15

CASE INLET	
Trin [°C] =	30.83

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	25.17
HOT FLUID OUT	
Trhx-2 [°C] =	9.13

EVAPORATOR INLET	
Tri-1 [°C] =	-34.02
Tri-2 [°C] =	-34.08
Tri-3 [°C] =	-33.93
Tri av [°C] =	-34.01
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-33.45
Tr1-2 [°C] =	-33.63
Tr1-3 [°C] =	-33.40
Tr1 av [°C] =	-33.49
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-32.62
Tr2-2 [°C] =	-31.49
Tr2-3 [°C] =	-32.60
Tr2 av [°C] =	-32.23
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-30.04
Tr3-2 [°C] =	-26.62
Tr3-3 [°C] =	-29.78
Tr3 av [°C] =	-28.81
EVAPORATOR OUTLET	
Tro-1 [°C] =	-23.85
Tro-2 [°C] =	-24.18
Tro-3 [°C] =	-24.42
Tro av [°C] =	-24.15
XCHR: COLD FLUID IN	
Trex [°C] =	-23.39
Trhx-4 [°C] =	-19.32
COLD FLUID OUT	
Trhx-3 [°C] =	-7.72

CASE OUTLET	
Trout [°C] =	-5.61

PACKAGE TEMPERATURES	
P-1 [°C] =	-22.55
P-2 [°C] =	-13.25
P-3 [°C] =	-15.97
P-4 [°C] =	-29.41
P-5 [°C] =	-24.77
P-6 [°C] =	-21.72
P-7 [°C] =	-21.30
P-8 [°C] =	-12.52
P-9 [°C] =	-15.44
P-10 [°C] =	-27.97
P-11 [°C] =	-22.70
P-12 [°C] =	-20.17

CASE AIR: DELIVERED	
Tad-1 [°C] =	-29.64
Tad-2 [°C] =	-29.64
Tad-3 [°C] =	-26.98
Tad-4 [°C] =	-24.44
Tad av [°C] =	-27.67
CASE AIR: CENTER	
Tac-1 [°C] =	24.64
Tac-2 [°C] =	-22.17
Tac-3 [°C] =	-31.19

CASE AIR: RETURNED	
Tar-1 [°C] =	-21.66
Tar-2 [°C] =	-21.90
Tar-3 [°C] =	-22.88
Tar-4 [°C] =	-20.81
Tar av [°C] =	-21.81

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	370.5
hl [kJ/kg] =	247.6
Qrt [kW] =	0.8575

EVAPORATOR LOAD	
ho [kJ/kg] =	355.0
hi [kJ/kg] =	213.3
Qevap [kW] =	0.9887

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.2393
Qvap [kW] =	0.1081

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-28.8	-23.05	-20.92	-21.95	-13.42	-16.18	-30.73	-25.66	-22.01	-23.18	-13.77	-16.21
2	-27.05	-22.75	-20.76	-19.08	-9.16	-15.11	-26.31	-24.84	-21.75	-21.29	-12.7	-14.14
3	-21.74	-21.3	-18.72	-16.32	-8.81	-11.59	-21.08	-22.09	-19.37	-17.43	-11.01	-10.52
4	-22.28	-21.11	-18.29	-17.93	-10.02	-11.93	-22.07	-22.15	-19.18	-18.58	-11.6	-11.56
5	-23.54	-21.09	-18.33	-18.95	-10.72	-12.59	-23.01	-22.25	-19.58	-19.66	-12.09	-12.65
6	-24.64	-21.14	-18.5	-19.49	-11.05	-13.02	-24.95	-22.23	-19.84	-20.17	-12.31	-13.35
7	-25.48	-21.21	-18.71	-19.84	-11.33	-13.4	-26.27	-22.34	-20.17	-20.48	-12.47	-13.91
8	-26.01	-21.28	-18.86	-20	-11.44	-13.71	-26.81	-22.49	-20.44	-20.62	-12.53	-14.23
9	-24.56	-22.05	-20.21	-17.36	-7.57	-13.67	-22.89	-23.55	-21.16	-20.74	-11.73	-12.16
AV	-24.90	-21.66	-19.26	-18.99	-10.39	-13.47	-24.90	-23.07	-20.39	-20.24	-12.25	-13.19

Warmest Test Package	-10.39
Coldest Test Package	-24.90
Average Test Package	-18.56

Average values of data during last 3/4's of running cycle (SI)

DATE:	072396-c
MINUTES:	

MASS FLOW RATE	
mdot [g/s] =	6.93

PRESSURES	*(Absolute)*
Prin [kPa] =	1878.07
Prout [kPa] =	167.70

POWER USAGE	
W1 [W] =	305.89
W2 [W] =	-0.03

GENERAL TEMPERATURES	
Tref [°C] =	25.30
Tdb [°C] =	24.75
Twb [°C] =	21.39

SAT TEMP (Prout)	
Tsat [°C] =	-34.67

SUPERHEAT	
[°C] =	11.37

CASE INLET	
Trin [°C] =	30.56

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	24.97
HOT FLUID OUT	
Trhx-2 [°C] =	8.98

EVAPORATOR INLET	
Tri-1 [°C] =	-34.15
Tri-2 [°C] =	-34.21
Tri-3 [°C] =	-34.02
Tri av [°C] =	-34.12
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-33.56
Tr1-2 [°C] =	-33.73
Tr1-3 [°C] =	-33.48
Tr1 av [°C] =	-33.59
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-32.68
Tr2-2 [°C] =	-30.42
Tr2-3 [°C] =	-32.43
Tr2 av [°C] =	-31.84
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-30.76
Tr3-2 [°C] =	-26.45
Tr3-3 [°C] =	-28.04
Tr3 av [°C] =	-28.41
EVAPORATOR OUTLET	
Tro-1 [°C] =	-23.97
Tro-2 [°C] =	-24.16
Tro-3 [°C] =	-24.28
Tro av [°C] =	-24.14
XCHR: COLD FLUID IN	
Trex [°C] =	-23.30
Trhx-4 [°C] =	-19.23
COLD FLUID OUT	
Trhx-3 [°C] =	-7.68

CASE OUTLET	
Trout [°C] =	-5.58

PACKAGE TEMPERATURES	
P-1 [°C] =	-22.56
P-2 [°C] =	-13.32
P-3 [°C] =	-15.93
P-4 [°C] =	-29.35
P-5 [°C] =	-24.72
P-6 [°C] =	-21.83
P-7 [°C] =	-21.37
P-8 [°C] =	-12.53
P-9 [°C] =	-15.44
P-10 [°C] =	-27.97
P-11 [°C] =	-22.82
P-12 [°C] =	-20.19

CASE AIR: DELIVERED	
Tad-1 [°C] =	-29.71
Tad-2 [°C] =	-29.60
Tad-3 [°C] =	-27.53
Tad-4 [°C] =	-24.25
Tad av [°C] =	-27.77
CASE AIR: CENTER	
Tac-1 [°C] =	24.59
Tac-2 [°C] =	-21.88
Tac-3 [°C] =	-31.20

CASE AIR: RETURNED	
Tar-1 [°C] =	-22.07
Tar-2 [°C] =	-21.88
Tar-3 [°C] =	-22.86
Tar-4 [°C] =	-20.68
Tar av [°C] =	-21.88

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	370.5
hl [kJ/kg] =	247.2
Qrt [kW] =	0.8539

EVAPORATOR LOAD	
ho [kJ/kg] =	355.0
hi [kJ/kg] =	213.1
Qevap [kW] =	0.9827

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.2362
Qvap [kW] =	0.1073

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-28.85	-23.95	-21.01	-22.18	-13.5	-16.34	-30.75	-25.95	-22.12	-23.89	-13.95	-16.34
2	-27.03	-23.51	-20.84	-19.5	-9.2	-15.24	-26.37	-25.06	-21.85	-21.45	-12.83	-14.2
3	-21.71	-21.45	-18.74	-16.7	-8.8	-11.72	-21.17	-22.26	-19.61	-17.85	-11.09	-10.56
4	-22.12	-21.21	-18.32	-18.09	-9.91	-11.92	-21.98	-22.14	-19.27	-18.75	-11.6	-11.48
5	-23.27	-21.18	-18.35	-19.03	-10.58	-12.52	-22.82	-22.15	-19.57	-19.77	-12.09	-12.52
6	-24.48	-21.21	-18.53	-19.53	-10.99	-13.04	-24.89	-22.24	-19.99	-20.37	-12.35	-13.26
7	-25.41	-21.23	-18.68	-19.84	-11.23	-13.58	-26.39	-22.57	-20.56	-20.72	-12.56	-13.88
8	-26.05	-21.35	-18.92	-20.21	-11.45	-13.87	-27.11	-22.7	-20.76	-20.94	-12.68	-14.33
9	-24.51	-22.62	-20.29	-18.08	-7.65	-13.79	-23	-23.73	-21.26	-20.9	-11.84	-12.22
AV	-24.83	-21.97	-19.30	-19.24	-10.37	-13.56	-24.94	-23.20	-20.55	-20.52	-12.33	-13.20

Warmest Test Package	-10.37
Coldest Test Package	-24.94
Average Test Package	-18.67

Average values of data during last 3/4's of running cycle (SI)

DATE:	072396-d
MINUTES:	

MASS FLOW RATE	
mdot [g/s] =	6.87

PRESSURES	*(Absolute)*
Prin [kPa] =	1874.93
Prout [kPa] =	167.16

POWER USAGE	
W1 [W] =	305.12
W2 [W] =	0.04

GENERAL TEMPERATURES	
Tref [°C] =	25.28
Tdb [°C] =	24.79
Twb [°C] =	22.88

SAT TEMP (Prout)	
Tsat [°C] =	-34.75

SUPERHEAT	
[°C] =	11.31

CASE INLET	
Trin [°C] =	30.43

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	24.80
HOT FLUID OUT	
Trhx-2 [°C] =	8.73

EVAPORATOR INLET	
Tri-1 [°C] =	-34.28
Tri-2 [°C] =	-34.35
Tri-3 [°C] =	-34.13
Tri av [°C] =	-34.25
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-33.69
Tr1-2 [°C] =	-33.85
Tr1-3 [°C] =	-33.58
Tr1 av [°C] =	-33.71
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-32.82
Tr2-2 [°C] =	-29.89
Tr2-3 [°C] =	-32.27
Tr2 av [°C] =	-31.66
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-31.63
Tr3-2 [°C] =	-26.39
Tr3-3 [°C] =	-26.67
Tr3 av [°C] =	-28.23
EVAPORATOR OUTLET	
Tro-1 [°C] =	-24.29
Tro-2 [°C] =	-24.31
Tro-3 [°C] =	-24.35
Tro av [°C] =	-24.32
XCHR: COLD FLUID IN	
Trex [°C] =	-23.44
Trhx-4 [°C] =	-19.39
COLD FLUID OUT	
Trhx-3 [°C] =	-7.85

CASE OUTLET	
Trout [°C] =	-5.71

PACKAGE TEMPERATURES	
P-1 [°C] =	-22.66
P-2 [°C] =	-13.29
P-3 [°C] =	-15.79
P-4 [°C] =	-29.41
P-5 [°C] =	-24.77
P-6 [°C] =	-21.72
P-7 [°C] =	-21.39
P-8 [°C] =	-12.49
P-9 [°C] =	-15.36
P-10 [°C] =	-28.05
P-11 [°C] =	-22.88
P-12 [°C] =	-20.09

CASE AIR: DELIVERED	
Tad-1 [°C] =	-29.74
Tad-2 [°C] =	-29.81
Tad-3 [°C] =	-29.47
Tad-4 [°C] =	-23.91
Tad av [°C] =	-28.23
CASE AIR: CENTER	
Tac-1 [°C] =	24.63
Tac-2 [°C] =	-21.69
Tac-3 [°C] =	-31.26

CASE AIR: RETURNED	
Tar-1 [°C] =	-21.33
Tar-2 [°C] =	-21.86
Tar-3 [°C] =	-22.76
Tar-4 [°C] =	-20.47
Tar av [°C] =	-21.61

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	370.4
hl [kJ/kg] =	246.9
Qrt [kW] =	0.8485

EVAPORATOR LOAD	
ho [kJ/kg] =	355.4
hi [kJ/kg] =	212.7
Qevap [kW] =	0.9804

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.2350
Qvap [kW] =	0.1031

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-28.73	-23.88	-20.81	-22.06	-13.43	-16.22	-30.66	-25.85	-22.26	-23.67	-13.91	-16.12
2	-26.95	-23.46	-20.66	-19.41	-9.25	-15.1	-26.37	-24.9	-21.91	-21.41	-12.78	-14.02
3	-21.62	-21.48	-18.65	-16.68	-8.84	-11.55	-21.06	-21.98	-19.44	-17.81	-11.04	-10.43
4	-22.05	-21.23	-18.21	-18.08	-9.88	-11.78	-21.89	-21.91	-19.2	-18.67	-11.53	-11.31
5	-23.28	-21.11	-18.21	-18.91	-10.54	-12.53	-22.94	-22.19	-19.8	-19.77	-12.04	-12.4
6	-24.4	-21.17	-18.37	-19.46	-10.92	-12.97	-24.92	-22.2	-20.02	-20.37	-12.27	-13.13
7	-25.32	-21.24	-18.61	-19.83	-11.17	-13.39	-26.33	-22.37	-20.35	-20.71	-12.47	-13.71
8	-26.03	-21.32	-18.79	-20.15	-11.35	-13.77	-27.18	-22.67	-20.68	-20.95	-12.61	-14.21
9	-24.52	-22.55	-20.09	-17.91	-7.7	-13.74	-23.14	-23.71	-21.46	-20.88	-11.84	-12.14
AV	-24.77	-21.94	-19.16	-19.17	-10.34	-13.45	-24.94	-23.09	-20.57	-20.47	-12.28	-13.05

Warmest Test Package	-10.34
Coldest Test Package	-24.94
Average Test Package	-18.60

Average values of data during last 3/4's of running cycle (SI)

DATE:	072396-e
MINUTES:	

MASS FLOW RATE	
mdot [g/s] =	6.91

PRESSURES	(Absolute)
Prin [kPa] =	1875.69
Prout [kPa] =	168.14

POWER USAGE	
W1 [W] =	305.55
W2 [W] =	0.04

GENERAL TEMPERATURES	
Tref [°C] =	26.45
Tdb [°C] =	25.67
Twb [°C] =	20.22

SAT TEMP (Prout)	
Tsat [°C] =	-34.61

SUPERHEAT	
[°C] =	11.68

CASE INLET	
Trin [°C] =	30.98

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	25.53
HOT FLUID OUT	
Trhx-2 [°C] =	9.43

EVAPORATOR INLET	
Tri-1 [°C] =	-34.16
Tri-2 [°C] =	-34.20
Tri-3 [°C] =	-33.99
Tri av [°C] =	-34.12
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-33.56
Tr1-2 [°C] =	-33.71
Tr1-3 [°C] =	-33.43
Tr1 av [°C] =	-33.56
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-32.64
Tr2-2 [°C] =	-29.58
Tr2-3 [°C] =	-31.69
Tr2 av [°C] =	-31.30
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-31.13
Tr3-2 [°C] =	-25.84
Tr3-3 [°C] =	-25.09
Tr3 av [°C] =	-27.35
EVAPORATOR OUTLET	
Tro-1 [°C] =	-23.83
Tro-2 [°C] =	-23.80
Tro-3 [°C] =	-23.78
Tro av [°C] =	-23.80
XCHR: COLD FLUID IN	
Trex [°C] =	-22.93
Trhx-4 [°C] =	-18.86
COLD FLUID OUT	
Trhx-3 [°C] =	-7.18

CASE OUTLET	
Trout [°C] =	-5.15

PACKAGE TEMPERATURES	
P-1 [°C] =	-22.39
P-2 [°C] =	-13.10
P-3 [°C] =	-15.54
P-4 [°C] =	-29.16
P-5 [°C] =	-24.70
P-6 [°C] =	-21.71
P-7 [°C] =	-21.23
P-8 [°C] =	-12.29
P-9 [°C] =	-15.21
P-10 [°C] =	-27.85
P-11 [°C] =	-22.81
P-12 [°C] =	-19.99

CASE AIR: DELIVERED	
Tad-1 [°C] =	-29.44
Tad-2 [°C] =	-29.48
Tad-3 [°C] =	-29.16
Tad-4 [°C] =	-23.48
Tad av [°C] =	-27.89
CASE AIR: CENTER	
Tac-1 [°C] =	25.48
Tac-2 [°C] =	-21.50
Tac-3 [°C] =	-31.05

CASE AIR: RETURNED	
Tar-1 [°C] =	-21.20
Tar-2 [°C] =	-21.79
Tar-3 [°C] =	-22.16
Tar-4 [°C] =	-19.91
Tar av [°C] =	-21.26

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	370.9
hl [kJ/kg] =	247.9
Qrt [kW] =	0.8504

EVAPORATOR LOAD	
ho [kJ/kg] =	355.8
hi [kJ/kg] =	213.7
Qevap [kW] =	0.9825

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.2365
Qvap [kW] =	0.1044

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-28.78	-24	-20.79	-22.14	-13.43	-16.08	-30.58	-25.79	-22.17	-23.83	-13.86	-15.92
2	-27.09	-23.57	-20.61	-19.46	-9.29	-15.05	-26.53	-24.93	-21.93	-21.44	-12.78	-13.96
3	-21.71	-21.49	-18.57	-16.76	-8.88	-11.61	-21.16	-22.1	-19.67	-18.02	-11.06	-10.45
4	-22.11	-21.25	-18.19	-18.17	-9.92	-11.81	-21.9	-21.97	-19.38	-18.72	-11.52	-11.29
5	-23.35	-21.21	-18.25	-19.05	-10.58	-12.5	-22.92	-22.15	-19.83	-19.87	-12.04	-12.39
6	-24.63	-21.19	-18.39	-19.51	-11.01	-13.12	-25.24	-22.43	-20.39	-20.51	-12.34	-13.2
7	-25.58	-21.31	-18.61	-19.98	-11.32	-13.48	-26.55	-22.53	-20.59	-20.92	-12.51	-13.78
8	-26.27	-21.5	-18.87	-20.39	-11.52	-13.84	-27.27	-22.72	-20.78	-21.11	-12.64	-14.24
9	-24.57	-22.68	-20.09	-18.04	-7.77	-13.65	-23.15	-23.63	-21.33	-20.91	-11.82	-12.07
AV	-24.90	-22.02	-19.15	-19.28	-10.41	-13.46	-25.03	-23.14	-20.67	-20.59	-12.29	-13.03

Warmest Test Package	-10.41
Coldest Test Package	-25.03
Average Test Package	-18.67

Average values of data during last 3/4's of running cycle (SI)

DATE:	081296-1
MINUTES:	

MASS FLOW RATE	
mdot [g/s] =	7.44

PRESSURES	(Absolute)
Prin [kPa] =	1843.22
Prout [kPa] =	173.11

POWER USAGE	
W1 [W] =	308.83
W2 [W] =	-0.03

GENERAL TEMPERATURES	
Tref [°C] =	26.19
Tdb [°C] =	25.41
Twb [°C] =	18.81

SAT TEMP (Prout)	
Tsat [°C] =	-33.93

SUPERHEAT	
[°C] =	6.88

CASE INLET	
Trin [°C] =	31.87

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	26.62
HOT FLUID OUT	
Trhx-2 [°C] =	9.31

EVAPORATOR INLET	
Tri-1 [°C] =	-33.41
Tri-2 [°C] =	-33.42
Tri-3 [°C] =	-33.22
Tri avg [°C] =	-33.35
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-33.11
Tr1-2 [°C] =	-33.12
Tr1-3 [°C] =	-32.99
Tr1 avg [°C] =	-33.07
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-32.28
Tr2-2 [°C] =	-32.86
Tr2-3 [°C] =	-32.48
Tr2 avg [°C] =	-32.54
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-32.41
Tr3-2 [°C] =	-31.10
Tr3-3 [°C] =	-31.45
Tr3 avg [°C] =	-31.65
EVAPORATOR OUTLET	
Tro-1 [°C] =	-27.73
Tro-2 [°C] =	-27.82
Tro-3 [°C] =	-28.84
Tro avg [°C] =	-28.13
XCHR: COLD FLUID IN	
Trex [°C] =	-27.05
Trhx-4 [°C] =	-23.45
COLD FLUID OUT	
Trhx-3 [°C] =	-9.33

CASE OUTLET	
Trout [°C] =	-7.52

PACKAGE TEMPERATURES	
P-1 [°C] =	-23.63
P-2 [°C] =	-13.48
P-3 [°C] =	-15.94
P-4 [°C] =	-29.36
P-5 [°C] =	-25.06
P-6 [°C] =	-22.04
P-7 [°C] =	-21.94
P-8 [°C] =	-12.61
P-9 [°C] =	-15.70
P-10 [°C] =	-28.50
P-11 [°C] =	-23.56
P-12 [°C] =	-20.51

CASE AIR: DELIVERED	
Tad-1 [°C] =	-29.75
Tad-2 [°C] =	-29.99
Tad-3 [°C] =	-29.38
Tad-4 [°C] =	-27.54
Tad avg [°C] =	-29.16
CASE AIR: CENTER	
Tac-1 [°C] =	25.30
Tac-2 [°C] =	-22.15
Tac-3 [°C] =	-30.67

CASE AIR: RETURNED	
Tar-1 [°C] =	-20.45
Tar-2 [°C] =	-22.01
Tar-3 [°C] =	-22.98
Tar-4 [°C] =	-21.62
Tar avg [°C] =	-21.76

htrkx1	240.554
Qliq	0.2011
Xin	0.274

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	368.9
hl [kJ/kg] =	249.4
Qrt [kW] =	0.8895

EVAPORATOR LOAD	
ho [kJ/kg] =	356.20
hi [kJ/kg] =	213.53
Qevap [kW] =	1.0620

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.2670
Qvap [kW] =	0.0945

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-28.87	-23.89	-20.71	-21.87	-12.89	-16.08	-30.16	-25.5	-22.27	-23.74	-13.37	-16.07
2	-26.28	-23.22	-20.47	-18.9	-9.08	-14.61	-25.34	-24.13	-21.76	-21.25	-12.31	-13.81
3	-23.13	-21.92	-19.14	-18.94	-10.34	-13.02	-22.62	-22.71	-20.13	-20.71	-11.87	-12.54
4	-24.25	-21.79	-19.02	-19.62	-11.08	-13.47	-24.66	-22.82	-20.14	-20.53	-12.26	-13.4
5	-25.43	-21.84	-19.14	-20.11	-11.47	-13.93	-26.29	-23.03	-20.49	-20.8	-12.56	-14.04
6	-26.35	-21.93	-19.29	-20.46	-11.74	-14.42	-27.29	-23.35	-20.99	-21.27	-12.78	-14.52
7	-26.92	-22.15	-19.5	-20.9	-11.91	-14.62	-27.71	-23.4	-21.08	-21.71	-12.88	-14.82
8	-27.42	-22.32	-19.66	-21.04	-12	-14.87	-28.14	-23.62	-21.36	-21.97	-12.98	-15.08
9	-26.28	-23.22	-20.47	-18.9	-9.08	-14.61	-25.34	-24.13	-21.76	-21.25	-12.31	-13.81
AV	-26.10	-22.48	-19.71	-20.08	-11.07	-14.40	-26.39	-23.63	-21.11	-21.47	-12.59	-14.23

Warmest Test Package	-11.07
Coldest Test Package	-26.39
Average Test Package	-19.44

Average values of data during last 3/4's of running cycle (SI)

DATE:	081496-1
MINUTES:	

MASS FLOW RATE	
mdot [g/s] =	7.76

PRESSURES	(Absolute)
Prin [kPa] =	1901.74
Prout [kPa] =	179.95

POWER USAGE	
W1 [W] =	306.56
W2 [W] =	0.07

GENERAL TEMPERATURES	
Tref [°C] =	26.29
Tdb [°C] =	25.33
Twb [°C] =	19.29

SAT TEMP (Prout)	
Tsat [°C] =	-33.02

SUPERHEAT	
[°C] =	2.47

CASE INLET	
Trin [°C] =	29.15

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	24.38
HOT FLUID OUT	
Trhx-2 [°C] =	-2.59

EVAPORATOR INLET	
Tri-1 [°C] =	-32.58
Tri-2 [°C] =	-32.67
Tri-3 [°C] =	-32.34
Tri av [°C] =	-32.53
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-32.38
Tr1-2 [°C] =	-32.36
Tr1-3 [°C] =	-32.29
Tr1 av [°C] =	-32.39
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-31.69
Tr2-2 [°C] =	-32.08
Tr2-3 [°C] =	-31.99
Tr2 av [°C] =	-32.04
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-31.88
Tr3-2 [°C] =	-31.40
Tr3-3 [°C] =	-31.78
Tr3 av [°C] =	-31.78
EVAPORATOR OUTLET	
Tro-1 [°C] =	-30.64
Tro-2 [°C] =	-30.25
Tro-3 [°C] =	-30.75
Tro av [°C] =	-30.85
XCHR: COLD FLUID IN	
Trex [°C] =	-30.55
Trhx-4 [°C] =	-30.82
COLD FLUID OUT	
Trhx-3 [°C] =	-19.32

CASE OUTLET	
Trout [°C] =	-17.65

PACKAGE TEMPERATURES	
P-1 [°C] =	-22.89
P-2 [°C] =	-13.37
P-3 [°C] =	-15.71
P-4 [°C] =	-28.95
P-5 [°C] =	-24.64
P-6 [°C] =	-21.66
P-7 [°C] =	-21.88
P-8 [°C] =	-12.69
P-9 [°C] =	-15.26
P-10 [°C] =	-28.19
P-11 [°C] =	-23.68
P-12 [°C] =	-20.43

CASE AIR: DELIVERED	
Tad-1 [°C] =	-29.24
Tad-2 [°C] =	-29.48
Tad-3 [°C] =	-28.62
Tad-4 [°C] =	-26.67
Tad av [°C] =	-28.50
CASE AIR: CENTER	
Tac-1 [°C] =	25.08
Tac-2 [°C] =	-21.66
Tac-3 [°C] =	-30.46

CASE AIR: RETURNED	
Tar-1 [°C] =	-19.33
Tar-2 [°C] =	-21.15
Tar-3 [°C] =	-22.22
Tar-4 [°C] =	-19.64
Tar av [°C] =	-20.59

h trhx 1	236.91
Qliq.	0.3126

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	360.53
hl [kJ/kg] =	244.76
Qrt [kW] =	0.8987

EVAPORATOR LOAD	
ho [kJ/kg] =	350.02
hi [kJ/kg] =	196.63
Qevap [kW] =	1.1907

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.3736
Qvap [kW] =	0.0816

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-28.55	-24.4	-21.18	-22.58	-13.08	-15.77	-29.57	-25.41	-21.92	-23.51	-13.8	-16.22
2	-24.56	-23.04	-20.42	-20.07	-9.39	-13.69	-23.32	-23.43	-21.32	-20.96	-12.27	-13.05
3	-23.01	-22.09	-19.33	-19.55	-10.67	-12.79	-22.62	-22.51	-20.89	-20.48	-12.19	-12.67
4	-24.43	-22	-19.25	-19.87	-11.41	-13.39	-25.01	-22.77	-20.85	-20.57	-12.66	-13.57
5	-25.57	-22.06	-19.33	-20.13	-11.68	-13.84	-26.45	-22.98	-20.88	-20.8	-12.87	-14.11
6	-26.37	-22.17	-19.44	-20.48	-11.91	-14.16	-27.1	-23.11	-20.95	-21.18	-12.99	-14.51
7	-26.94	-22.35	-19.59	-20.83	-12.09	-14.45	-27.56	-23.26	-21.04	-21.58	-13.07	-14.78
8	-27.36	-22.56	-19.73	-21.07	-12.17	-14.69	-27.87	-23.4	-21.16	-21.84	-13.14	-14.99
9	-26.25	-23.7	-20.85	-20.34	-9.04	-14.54	-25.41	-24.28	-21.58	-21.2	-12.72	-14.04
AV	-25.89	-22.71	-19.90	-20.55	-11.27	-14.15	-26.10	-23.46	-21.18	-21.35	-12.86	-14.22

Warmest Test Package	-11.27
Coldest Test Package	-26.10
Average Test Package	-19.47

Average values of data during last 3/4's of running cycle (SI)

DATE:	082696-1
MINUTES:	

MASS FLOW RATE	
mdot [g/s] =	6.61

PRESSURES	(Absolute)
Prin [kPa] =	1940.51
Prout [kPa] =	206.56

POWER USAGE	
W1 [W] =	297.56
W2 [W] =	0.14

GENERAL TEMPERATURES	
Tref [°C] =	26.40
Tdb [°C] =	26.24
Twb [°C] =	20.23

SAT TEMP (Prout)	
Tsat [°C] =	-29.71

SUPERHEAT	
[°C] =	6.44

CASE INLET	
Trin [°C] =	30.36

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	25.32
HOT FLUID OUT	
Trhx-2 [°C] =	8.72

EVAPORATOR INLET	
Tri-1 [°C] =	-29.31
Tri-2 [°C] =	-29.38
Tri-3 [°C] =	-28.95
Tri av [°C] =	-29.21
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-29.00
Tr1-2 [°C] =	-28.99
Tr1-3 [°C] =	-28.89
Tr1 av [°C] =	-28.96
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-28.14
Tr2-2 [°C] =	-28.52
Tr2-3 [°C] =	-28.35
Tr2 av [°C] =	-28.34
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-28.16
Tr3-2 [°C] =	-26.81
Tr3-3 [°C] =	-27.27
Tr3 av [°C] =	-27.41
EVAPORATOR OUTLET	
Tro-1 [°C] =	-23.61
Tro-2 [°C] =	-23.76
Tro-3 [°C] =	-24.89
Tro av [°C] =	-24.09
XCHR: COLD FLUID IN	
Trex [°C] =	-23.27
Trhx-4 [°C] =	-20.31
COLD FLUID OUT	
Trhx-3 [°C] =	-7.21

CASE OUTLET	
Trout [°C] =	-5.54

PACKAGE TEMPERATURES	
P-1 [°C] =	-19.33
P-2 [°C] =	-10.04
P-3 [°C] =	-12.00
P-4 [°C] =	-25.59
P-5 [°C] =	-20.80
P-6 [°C] =	-18.29
P-7 [°C] =	-18.33
P-8 [°C] =	-9.09
P-9 [°C] =	-12.62
P-10 [°C] =	-24.26
P-11 [°C] =	-19.46
P-12 [°C] =	-17.11

CASE AIR: DELIVERED	
Tad-1 [°C] =	-25.63
Tad-2 [°C] =	-25.64
Tad-3 [°C] =	-25.30
Tad-4 [°C] =	-22.83
Tad av [°C] =	-24.85
CASE AIR: CENTER	
Tac-1 [°C] =	25.82
Tac-2 [°C] =	-18.24
Tac-3 [°C] =	-27.22

CASE AIR: RETURNED	
Tar-1 [°C] =	-19.52
Tar-2 [°C] =	-19.08
Tar-3 [°C] =	-18.29
Tar-4 [°C] =	-15.43
Tar av [°C] =	-18.08

h thrx 1	238.41
Qliq	0.1701

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	369.99
hl [kJ/kg] =	246.81
Qrt [kW] =	0.8144

EVAPORATOR LOAD	
ho [kJ/kg] =	353.29
hi [kJ/kg] =	212.68
Qevap [kW] =	0.9296

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.2256
Qvap [kW] =	0.1104

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-24.04	-19.52	-17.07	-18.02	-8.93	-12.36	-25.28	-20.69	-18.41	-19.13	-9.96	-12.29
2	-22.86	-19.53	-17.01	-15.49	-5.31	-11.78	-22.94	-20.56	-18.39	-17.8	-9.47	-11.23
3	-21.04	-18.77	-15.98	-13.88	-7.53	-10.39	-20.92	-19.51	-16.9	-14.5	-9	-9.87
4	-21.29	-18.63	-15.79	-15.14	-8.18	-10.65	-21.33	-19.68	-16.69	-15.9	-9.25	-10.38
5	-21.89	-18.65	-15.87	-16.14	-8.54	-11.02	-22.02	-19.82	-16.92	-17.32	-9.5	-10.9
6	-22.43	-18.7	-15.99	-16.75	-8.73	-11.31	-22.51	-19.89	-17.15	-18.12	-9.66	-11.2
7	-22.93	-18.73	-16.05	-17.2	-8.81	-11.5	-23.14	-19.89	-17.26	-18.52	-9.71	-11.34
8	-23.28	-18.8	-16.17	-17.63	-8.77	-11.73	-23.86	-19.95	-17.39	-18.8	-9.79	-11.51
9	-23.16	-19.54	-17.04	-15.88	-5.257	-11.9	-23.38	-20.61	-18.41	-18.12	-9.51	-11.41
AV	-22.55	-18.99	-16.33	-16.24	-7.78	-11.40	-22.82	-20.07	-17.50	-17.58	-9.54	-11.13

Warmest Test Package	-7.78
Coldest Test Package	-22.82
Average Test Package	-15.99

Average values of data during last 3/4's of running cycle (SI)

DATE:	082896-1
MINUTES:	

MASS FLOW RATE	
mdot [g/s] =	6.90

PRESSURES	(Absolute)
Prin [kPa] =	1917.06
Prout [kPa] =	202.55

POWER USAGE	
W1 [W] =	288.06
W2 [W] =	0.21

GENERAL TEMPERATURES	
Tref [°C] =	26.21
Tdb [°C] =	25.15
Twb [°C] =	19.24

SAT TEMP (Prout)	
Tsat [°C] =	-30.19

SUPERHEAT	
[°C] =	6.79

CASE INLET	
Trin [°C] =	30.10

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	25.09
HOT FLUID OUT	
Trhx-2 [°C] =	8.90

EVAPORATOR INLET	
Tri-1 [°C] =	-29.70
Tri-2 [°C] =	-29.76
Tri-3 [°C] =	-29.38
Tri av [°C] =	-29.61
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-29.40
Tr1-2 [°C] =	-29.40
Tr1-3 [°C] =	-29.34
Tr1 av [°C] =	-29.38
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-28.66
Tr2-2 [°C] =	-28.97
Tr2-3 [°C] =	-28.86
Tr2 av [°C] =	-28.83
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-28.67
Tr3-2 [°C] =	-27.03
Tr3-3 [°C] =	-27.97
Tr3 av [°C] =	-27.89
EVAPORATOR OUTLET	
Tro-1 [°C] =	-23.61
Tro-2 [°C] =	-24.02
Tro-3 [°C] =	-25.02
Tro av [°C] =	-24.22
XCHR: COLD FLUID IN	
Trex [°C] =	-23.40
Trhx-4 [°C] =	-19.89
COLD FLUID OUT	
Trhx-3 [°C] =	-7.40

CASE OUTLET	
Trout [°C] =	-5.72

PACKAGE TEMPERATURES	
P-1 [°C] =	-20.41
P-2 [°C] =	-11.01
P-3 [°C] =	-13.32
P-4 [°C] =	-25.94
P-5 [°C] =	-21.60
P-6 [°C] =	-19.64
P-7 [°C] =	-19.29
P-8 [°C] =	-9.82
P-9 [°C] =	-13.23
P-10 [°C] =	-25.16
P-11 [°C] =	-20.34
P-12 [°C] =	-18.05

CASE AIR: DELIVERED	
Tad-1 [°C] =	-26.28
Tad-2 [°C] =	-26.41
Tad-3 [°C] =	-26.11
Tad-4 [°C] =	-23.94
Tad av [°C] =	-25.68
CASE AIR: CENTER	
Tac-1 [°C] =	25.40
Tac-2 [°C] =	-19.76
Tac-3 [°C] =	-27.46

CASE AIR: RETURNED	
Tar-1 [°C] =	-19.96
Tar-2 [°C] =	-20.19
Tar-3 [°C] =	-20.30
Tar-4 [°C] =	-18.39
Tar av [°C] =	-19.71

htrhx-1	238.04
Qliq	0.1731

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	369.88
hl [kJ/kg] =	246.37
Qrt [kW] =	0.8522

EVAPORATOR LOAD	
ho [kJ/kg] =	354.92
hi [kJ/kg] =	212.95
Qevap [kW] =	0.9796

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.2306
Qvap [kW] =	0.1032

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-25.04	-20.51	-18.1	-19.03	-9.79	-13.34	-26.11	-21.62	-19.59	-20.47	-10.83	-13.21
2	-23.3	-20.46	-17.94	-15.82	-5.672	-12.42	-23.02	-21.33	-19.43	-18.3	-10.19	-11.8
3	-21.29	-19.64	-16.86	-14.76	-8.3	-11.12	-21.07	-20.26	-17.93	-15.41	-9.84	-10.66
4	-22.26	-19.49	-16.79	-16.39	-9	-11.63	-22.26	-20.43	-18.03	-17.4	-10.15	-11.44
5	-23.2	-19.49	-16.97	-17.37	-9.23	-12.03	-23.23	-20.57	-18.45	-18.67	-10.41	-11.98
6	-23.91	-19.54	-17.16	-18.04	-9.42	-12.35	-24.55	-20.71	-18.77	-19.37	-10.59	-12.38
7	-24.4	-19.62	-17.34	-18.53	-9.58	-12.61	-25.15	-20.86	-19.04	-19.85	-10.72	-12.58
8	-24.7	-19.68	-17.48	-18.88	-9.6	-12.72	-25.38	-20.93	-19.21	-20.16	-10.74	-12.64
9	-23.65	-20.48	-17.99	-16.21	-5.484	-12.57	-23.48	-21.41	-19.47	-18.7	-10.26	-12
AV	-23.53	-19.88	-17.40	-17.23	-8.45	-12.31	-23.81	-20.90	-18.88	-18.70	-10.41	-12.08

Warmest Test Package	-8.45
Coldest Test Package	-23.81
Average Test Package	-16.97

Average values of data during last 3/4's of running cycle (SI)

DATE:	090596-a
MINUTES:	

MASS FLOW RATE	
mdot [g/s] =	6.95

PRESSURES	(Absolute)
Prin [kPa] =	1823.81
Prout [kPa] =	193.43

POWER USAGE	
W1 [W] =	306.37
W2 [W] =	0.01

GENERAL TEMPERATURES	
Tref [°C] =	26.22
Tdb [°C] =	25.70
Twb [°C] =	19.66

SAT TEMP (Prout)	
Tsat [°C] =	-31.30

SUPERHEAT	
[°C] =	5.74

CASE INLET	
Trin [°C] =	29.20

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	24.17
HOT FLUID OUT	
Trhx-2 [°C] =	7.65

EVAPORATOR INLET	
Tri-1 [°C] =	-30.94
Tri-2 [°C] =	-31.00
Tri-3 [°C] =	-30.69
Tri av [°C] =	-30.88
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-30.68
Tr1-2 [°C] =	-30.67
Tr1-3 [°C] =	-30.60
Tr1 av [°C] =	-30.65
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-30.16
Tr2-2 [°C] =	-30.28
Tr2-3 [°C] =	-30.14
Tr2 av [°C] =	-30.19
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-29.96
Tr3-2 [°C] =	-29.06
Tr3-3 [°C] =	-29.27
Tr3 av [°C] =	-29.43
EVAPORATOR OUTLET	
Tro-1 [°C] =	-26.09
Tro-2 [°C] =	-26.20
Tro-3 [°C] =	-27.32
Tro av [°C] =	-26.54
XCHR: COLD FLUID IN	
Trex [°C] =	-25.56
Trhx-4 [°C] =	-22.36
COLD FLUID OUT	
Trhx-3 [°C] =	-9.00

CASE OUTLET	
Trout [°C] =	-7.27

PACKAGE TEMPERATURES	
P-1 [°C] =	-21.39
P-2 [°C] =	-11.89
P-3 [°C] =	-14.34
P-4 [°C] =	-27.27
P-5 [°C] =	-22.20
P-6 [°C] =	-20.50
P-7 [°C] =	-20.21
P-8 [°C] =	-10.58
P-9 [°C] =	-14.08
P-10 [°C] =	-26.40
P-11 [°C] =	-21.26
P-12 [°C] =	-19.01

CASE AIR: DELIVERED	
Tad-1 [°C] =	-27.59
Tad-2 [°C] =	-27.70
Tad-3 [°C] =	-27.25
Tad-4 [°C] =	-24.80
Tad av [°C] =	-26.83
CASE AIR: CENTER	
Tac-1 [°C] =	25.41
Tac-2 [°C] =	-20.53
Tac-3 [°C] =	-28.76

CASE AIR: RETURNED	
Tar-1 [°C] =	-20.52
Tar-2 [°C] =	-19.97
Tar-3 [°C] =	-21.22
Tar-4 [°C] =	-19.13
Tar av [°C] =	-20.21

h + hrx 1	236.57
Qliq	0.1772

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	368.77
hl [kJ/kg] =	244.84
Qrt [kW] =	0.8615

EVAPORATOR LOAD	
ho [kJ/kg] =	353.20
hi [kJ/kg] =	211.08
Qevap [kW] =	0.9879

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.2347
Qvap [kW] =	0.1082

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-26.31	-21.25	-19	-20.15	-10.33	-14.06	-27.47	-22.14	-20.31	-21.12	-11.4	-14.31
2	-24.5	-21.16	-18.85	-16.78	-6.318	-13.11	-23.79	-21.8	-20.15	-19.15	-10.7	-12.77
3	-21.86	-20.29	-17.65	-15.59	-8.56	-11.63	-21.28	-20.61	-18.52	-17.04	-10.33	-11.42
4	-23.16	-20.16	-17.58	-17.39	-9.42	-12.2	-22.8	-20.72	-18.68	-18.62	-10.75	-12.26
5	-24.42	-20.17	-17.8	-18.57	-9.67	-12.67	-24.99	-20.97	-19.17	-19.78	-11.01	-12.9
6	-25.08	-20.25	-18	-19.22	-9.97	-12.99	-25.94	-21.19	-19.48	-20.3	-11.2	-13.26
7	-25.64	-20.35	-18.2	-19.65	-10.09	-13.25	-26.51	-21.39	-19.79	-20.76	-11.35	-13.56
8	-25.98	-20.49	-18.37	-19.95	-10.18	-13.46	-26.79	-21.62	-19.99	-21.12	-11.46	-13.66
9	-24.5	-21.16	-18.85	-16.78	-6.318	-13.11	-23.79	-21.8	-20.15	-19.15	-10.7	-12.77
AV	-24.61	-20.59	-18.26	-18.23	-8.98	-12.94	-24.82	-21.36	-19.58	-19.67	-10.99	-12.99

Warmest Test Package	-8.98
Coldest Test Package	-24.82
Average Test Package	-17.75

Average values of data during last 3/4's of running cycle (SI)

DATE:	090596-b
MINUTES:	

MASS FLOW RATE	
mdot [g/s] =	6.91

PRESSURES	(Absolute)
Prin [kPa] =	1818.02
Prout [kPa] =	191.54

POWER USAGE	
W1 [W] =	305.41
W2 [W] =	0.10

GENERAL TEMPERATURES	
Tref [°C] =	25.79
Tdb [°C] =	25.46
Twb [°C] =	19.85

SAT TEMP (Prout)	
Tsat [°C] =	-31.53

SUPERHEAT	
[°C] =	5.53

CASE INLET	
Trin [°C] =	28.87

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	23.84
HOT FLUID OUT	
Trhx-2 [°C] =	7.23

EVAPORATOR INLET	
Tri-1 [°C] =	-31.21
Tri-2 [°C] =	-31.28
Tri-3 [°C] =	-30.97
Tri av [°C] =	-31.15
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-30.95
Tr1-2 [°C] =	-30.93
Tr1-3 [°C] =	-30.88
Tr1 av [°C] =	-30.92
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-30.45
Tr2-2 [°C] =	-30.54
Tr2-3 [°C] =	-30.46
Tr2 av [°C] =	-30.49
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-30.28
Tr3-2 [°C] =	-29.36
Tr3-3 [°C] =	-29.04
Tr3 av [°C] =	-29.56
EVAPORATOR OUTLET	
Tro-1 [°C] =	-26.76
Tro-2 [°C] =	-26.67
Tro-3 [°C] =	-27.82
Tro av [°C] =	-27.08
XCHR: COLD FLUID IN	
Trex [°C] =	-26.00
Trhx-4 [°C] =	-22.83
COLD FLUID OUT	
Trhx-3 [°C] =	-9.26

CASE OUTLET	
Trout [°C] =	-7.52

PACKAGE TEMPERATURES	
P-1 [°C] =	-21.71
P-2 [°C] =	-12.24
P-3 [°C] =	-14.27
P-4 [°C] =	-27.49
P-5 [°C] =	-23.01
P-6 [°C] =	-20.73
P-7 [°C] =	-20.67
P-8 [°C] =	-10.90
P-9 [°C] =	-14.27
P-10 [°C] =	-26.74
P-11 [°C] =	-21.67
P-12 [°C] =	-19.14

CASE AIR: DELIVERED	
Tad-1 [°C] =	-27.85
Tad-2 [°C] =	-27.89
Tad-3 [°C] =	-27.47
Tad-4 [°C] =	-25.02
Tad av [°C] =	-27.06
CASE AIR: CENTER	
Tac-1 [°C] =	25.18
Tac-2 [°C] =	-20.66
Tac-3 [°C] =	-28.95

CASE AIR: RETURNED	
Tar-1 [°C] =	-20.35
Tar-2 [°C] =	-20.11
Tar-3 [°C] =	-21.38
Tar-4 [°C] =	-19.71
Tar av [°C] =	-20.39

hthrx 1	236.03
Qliq	0.1768

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	368.60
hl [kJ/kg] =	244.28
Qrt [kW] =	0.8584

EVAPORATOR LOAD	
ho [kJ/kg] =	352.81
hi [kJ/kg] =	210.45
Qevap [kW] =	0.9830

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.2336
Qvap [kW] =	0.1090

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-26.46	-21.95	-19.21	-20.31	-10.93	-14.27	-27.66	-22.19	-20.6	-21.47	-12.17	-14.34
2	-24.66	-21.83	-19.01	-16.89	-6.339	-13.22	-24.06	-21.73	-20.41	-19.56	-11.3	-12.76
3	-21.8	-20.91	-17.77	-15.55	-8.83	-11.61	-21.22	-21.07	-18.71	-18.27	-10.81	-11.3
4	-23.13	-20.72	-17.7	-17.43	-9.76	-12.24	-22.8	-21.1	-18.84	-19.43	-11.25	-12.17
5	-24.45	-20.69	-17.91	-18.68	-10.03	-12.74	-25.08	-21.33	-19.32	-20.13	-11.55	-12.84
6	-25.22	-20.73	-18.11	-19.33	-10.3	-13.08	-26.12	-21.58	-19.65	-20.41	-11.72	-13.28
7	-25.75	-20.8	-18.29	-19.71	-10.43	-13.34	-26.61	-21.8	-19.89	-20.71	-11.81	-13.48
8	-26.11	-20.92	-18.47	-19.97	-10.47	-13.52	-26.92	-21.98	-20.09	-21.06	-11.88	-13.61
9	-24.66	-21.83	-19.01	-16.89	-6.339	-13.22	-24.06	-21.73	-20.41	-19.56	-11.3	-12.76
AV	-24.69	-21.15	-18.39	-18.31	-9.27	-13.03	-24.95	-21.61	-19.77	-20.07	-11.53	-12.95

Warmest Test Package	-9.27
Coldest Test Package	-24.95
Average Test Package	-17.98

Average values of data during last 3/4's of running cycle (SI)

DATE:	090996-1
MINUTES:	

MASS FLOW RATE	
mdot [g/s] =	6.86

PRESSURES	(Absolute)
Prin [kPa] =	1815.79
Prout [kPa] =	191.54

POWER USAGE	
W1 [W] =	306.65
W2 [W] =	0.14

GENERAL TEMPERATURES	
Tref [°C] =	25.72
Tdb [°C] =	25.24
Twb [°C] =	19.14

SAT TEMP (Prout)	
Tsat [°C] =	-31.27

SUPERHEAT	
[°C] =	5.63

CASE INLET	
Trin [°C] =	28.67

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	23.57
HOT FLUID OUT	
Trhx-2 [°C] =	7.17

EVAPORATOR INLET	
Tri-1 [°C] =	-31.14
Tri-2 [°C] =	-31.20
Tri-3 [°C] =	-30.91
Tri av [°C] =	-31.08
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-30.86
Tr1-2 [°C] =	-30.85
Tr1-3 [°C] =	-30.77
Tr1 av [°C] =	-30.83
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-30.36
Tr2-2 [°C] =	-30.46
Tr2-3 [°C] =	-30.29
Tr2 av [°C] =	-30.37
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-30.16
Tr3-2 [°C] =	-29.19
Tr3-3 [°C] =	-29.40
Tr3 av [°C] =	-29.58
EVAPORATOR OUTLET	
Tro-1 [°C] =	-26.17
Tro-2 [°C] =	-26.30
Tro-3 [°C] =	-27.40
Tro av [°C] =	-26.62
XCHR: COLD FLUID IN	
Trex [°C] =	-25.64
Trhx-4 [°C] =	-22.32
COLD FLUID OUT	
Trhx-3 [°C] =	-9.28

CASE OUTLET	
Trout [°C] =	-7.51

PACKAGE TEMPERATURES	
P-1 [°C] =	-21.80
P-2 [°C] =	-12.46
P-3 [°C] =	-14.59
P-4 [°C] =	-27.51
P-5 [°C] =	-23.34
P-6 [°C] =	-20.87
P-7 [°C] =	-20.65
P-8 [°C] =	-11.18
P-9 [°C] =	-14.57
P-10 [°C] =	-26.65
P-11 [°C] =	-21.68
P-12 [°C] =	-19.32

CASE AIR: DELIVERED	
Tad-1 [°C] =	-27.81
Tad-2 [°C] =	-27.85
Tad-3 [°C] =	-27.52
Tad-4 [°C] =	-25.03
Tad av [°C] =	-27.05
CASE AIR: CENTER	
Tac-1 [°C] =	24.97
Tac-2 [°C] =	-20.96
Tac-3 [°C] =	-28.94

CASE AIR: RETURNED	
Tar-1 [°C] =	-20.83
Tar-2 [°C] =	-20.99
Tar-3 [°C] =	-21.55
Tar-4 [°C] =	-19.54
Tar av [°C] =	-20.73

htrhx-1	235.57
Qliq	0.1729

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	368.62
hl [kJ/kg] =	243.82
Qrt [kW] =	0.8561

EVAPORATOR LOAD	
ho [kJ/kg] =	353.20
hi [kJ/kg] =	210.36
Qevap [kW] =	0.9798

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.2295
Qvap [kW] =	0.1058

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-26.82	-22	-19.54	-20.78	-11.35	-14.64	-27.84	-23.53	-21.03	-21.88	-12.53	-14.6
2	-25.03	-21.85	-19.34	-17.37	-6.656	-13.57	-24.28	-22.74	-20.81	-20.42	-11.67	-13.05
3	-22.05	-21.05	-18.08	-15.94	-9.22	-11.95	-21.43	-21.39	-19.1	-19.19	-11.17	-11.59
4	-23.4	-20.87	-18.01	-17.7	-10.09	-12.57	-23.07	-21.58	-19.22	-19.93	-11.6	-12.45
5	-24.45	-20.86	-18.16	-18.7	-10.31	-13.04	-25.1	-21.83	-19.59	-20.23	-11.84	-13.01
6	-25.07	-20.88	-18.32	-19.3	-10.43	-13.35	-25.91	-21.99	-19.86	-20.44	-11.98	-13.33
7	-25.48	-20.93	-18.48	-19.66	-10.68	-13.59	-26.32	-22.14	-20.04	-20.77	-12.08	-13.5
8	-25.76	-21.03	-18.62	-19.94	-10.77	-13.72	-26.58	-22.32	-20.2	-21.08	-12.18	-13.63
9	-25.03	-21.85	-19.34	-17.37	-6.656	-13.57	-24.28	-22.74	-20.81	-20.42	-11.67	-13.05
AV	-24.79	-21.26	-18.65	-18.53	-9.57	-13.33	-24.98	-22.25	-20.07	-20.48	-11.86	-13.13

Warmest Test Package	-9.57
Coldest Test Package	-24.98
Average Test Package	-18.24

Average values of data during last 3/4's of running cycle (SI)

DATE:	
MINUTES:	091496-1

MASS FLOW RATE	
mdot [g/s] =	6.37

PRESSURES	(Absolute)
Prin [kPa] =	1820.69
Prout [kPa] =	235.64

POWER USAGE	
W1 [W] =	310.03
W2 [W] =	-0.09

GENERAL TEMPERATURES	
Tref [°C] =	24.45
Tdb [°C] =	24.27
Twb [°C] =	16.46

SAT TEMP (Prout)	
Tsat [°C] =	-26.43

SUPERHEAT	
[°C] =	4.34

CASE INLET	
Trin [°C] =	28.28

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	23.26
HOT FLUID OUT	
Trhx-2 [°C] =	7.15

EVAPORATOR INLET	
Tri-1 [°C] =	-26.22
Tri-2 [°C] =	-26.30
Tri-3 [°C] =	-26.07
Tri av [°C] =	-26.19
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-25.97
Tr1-2 [°C] =	-25.96
Tr1-3 [°C] =	-25.91
Tr1 av [°C] =	-25.95
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-25.53
Tr2-2 [°C] =	-25.56
Tr2-3 [°C] =	-25.55
Tr2 av [°C] =	-25.55
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-25.35
Tr3-2 [°C] =	-24.06
Tr3-3 [°C] =	-24.78
Tr3 av [°C] =	-24.73
EVAPORATOR OUTLET	
Tro-1 [°C] =	-22.26
Tro-2 [°C] =	-22.29
Tro-3 [°C] =	-23.33
Tro av [°C] =	-22.63
XCHR: COLD FLUID IN	
Trex [°C] =	-22.09
Trhx-4 [°C] =	-19.43
COLD FLUID OUT	
Trhx-3 [°C] =	-6.97

CASE OUTLET	
Trout [°C] =	-5.71

PACKAGE TEMPERATURES	
P-1 [°C] =	-18.05
P-2 [°C] =	-9.14
P-3 [°C] =	-11.21
P-4 [°C] =	-22.99
P-5 [°C] =	-19.43
P-6 [°C] =	-17.35
P-7 [°C] =	-16.86
P-8 [°C] =	-7.58
P-9 [°C] =	-11.17
P-10 [°C] =	-22.25
P-11 [°C] =	-17.82
P-12 [°C] =	-15.64

CASE AIR: DELIVERED	
Tad-1 [°C] =	-23.50
Tad-2 [°C] =	-23.41
Tad-3 [°C] =	-23.09
Tad-4 [°C] =	-20.21
Tad av [°C] =	-22.55
CASE AIR: CENTER	
Tac-1 [°C] =	24.27
Tac-2 [°C] =	-17.18
Tac-3 [°C] =	-24.23

CASE AIR: RETURNED	
Tar-1 [°C] =	-17.35
Tar-2 [°C] =	-18.28
Tar-3 [°C] =	-18.16
Tar-4 [°C] =	-16.19
Tar av [°C] =	-17.50

h trhx-1	235.04
Qliq	0.1574

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	369.40
hl [kJ/kg] =	243.28
Qrt [kW] =	0.8038

EVAPORATOR LOAD	
ho [kJ/kg] =	355.60
hi [kJ/kg] =	210.33
Qevap [kW] =	0.9259

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.2100
Qvap [kW] =	0.0880

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-21.72	-17.58	-15.31	-16.09	-7.31	-10.94	-22.49	-19.29	-17	-17.31	-8.94	-10.89
2	-21.2	-17.56	-15.25	-13.74	-3.095	-10.39	-21.32	-19.13	-16.96	-16.05	-8.42	-9.97
3	-20.9	-16.92	-14.49	-13.11	-6.549	-9.55	-20.85	-18.23	-15.9	-13.66	-8.29	-9.24
4	-20.91	-16.82	-14.43	-14.29	-7.05	-9.87	-21.14	-18.37	-15.93	-15	-8.46	-9.69
5	-21.13	-16.85	-14.55	-15.06	-7.24	-10.19	-21.58	-18.57	-16.24	-16.2	-8.61	-10.08
6	-21.44	-16.92	-14.72	-15.65	-7.43	-10.43	-21.8	-18.75	-16.51	-17.06	-8.74	-10.38
7	-21.71	-17.05	-14.93	-16.15	-7.52	-10.65	-22.11	-18.95	-16.79	-17.69	-8.87	-10.64
8	-22	-17.17	-15.12	-16.55	-7.63	-10.83	-22.56	-19.11	-17.01	-18.09	-8.96	-10.83
9	-21.26	-17.57	-15.26	-14	-2.811	-10.47	-21.43	-19.18	-16.98	-16.31	-8.45	-10.1
AV	-21.36	-17.16	-14.90	-14.96	-6.29	-10.37	-21.70	-18.84	-16.59	-16.37	-8.64	-10.20

Warmest Test Package	-6.29
Coldest Test Package	-21.70
Average Test Package	-14.78

Average values of data during last 3/4's of running cycle (SI)

DATE:	091796-1
MINUTES:	

MASS FLOW RATE	
mdot [g/s] =	6.02

PRESSURES	(Absolute)
Prin [kPa] =	1830.73
Prout [kPa] =	243.91

POWER USAGE	
W1 [W] =	309.71
W2 [W] =	-0.13

GENERAL TEMPERATURES	
Tref [°C] =	24.21
Tdb [°C] =	24.08
Twb [°C] =	17.24

SAT TEMP (Prout)	
Tsat [°C] =	-25.56

SUPERHEAT	
[°C] =	9.01

CASE INLET	
Trin [°C] =	28.07

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	23.07
HOT FLUID OUT	
Trhx-2 [°C] =	9.21

EVAPORATOR INLET	
Tri-1 [°C] =	-25.25
Tri-2 [°C] =	-25.32
Tri-3 [°C] =	-25.02
Tri av [°C] =	-25.19
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-24.87
Tr1-2 [°C] =	-24.85
Tr1-3 [°C] =	-24.76
Tr1 av [°C] =	-24.82
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-24.26
Tr2-2 [°C] =	-23.35
Tr2-3 [°C] =	-23.61
Tr2 av [°C] =	-23.74
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-23.15
Tr3-2 [°C] =	-19.14
Tr3-3 [°C] =	-18.71
Tr3 av [°C] =	-20.33
EVAPORATOR OUTLET	
Tro-1 [°C] =	-17.01
Tro-2 [°C] =	-17.34
Tro-3 [°C] =	-17.42
Tro av [°C] =	-17.25
XCHR: COLD FLUID IN	
Trex [°C] =	-16.55
Trhx-4 [°C] =	-12.88
COLD FLUID OUT	
Trhx-3 [°C] =	-3.32

CASE OUTLET	
Trout [°C] =	-1.92

PACKAGE TEMPERATURES	
P-1 [°C] =	-16.26
P-2 [°C] =	-8.20
P-3 [°C] =	-9.92
P-4 [°C] =	-21.19
P-5 [°C] =	-17.89
P-6 [°C] =	-15.82
P-7 [°C] =	-15.13
P-8 [°C] =	-6.61
P-9 [°C] =	-10.11
P-10 [°C] =	-20.82
P-11 [°C] =	-16.39
P-12 [°C] =	-14.25

CASE AIR: DELIVERED	
Tad-1 [°C] =	-21.68
Tad-2 [°C] =	-21.48
Tad-3 [°C] =	-21.37
Tad-4 [°C] =	-17.36
Tad av [°C] =	-20.47
CASE AIR: CENTER	
Tac-1 [°C] =	24.22
Tac-2 [°C] =	-15.31
Tac-3 [°C] =	-22.43

CASE AIR: RETURNED	
Tar-1 [°C] =	-15.94
Tar-2 [°C] =	-16.50
Tar-3 [°C] =	-16.49
Tar-4 [°C] =	-14.14
Tar av [°C] =	-15.77

h trhx-1	234.72
Qliq	0.1252

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	372.45
hl [kJ/kg] =	242.92
Qrt [kW] =	0.7802

EVAPORATOR LOAD	
ho [kJ/kg] =	359.76
hi [kJ/kg] =	213.94
Qevap [kW] =	0.8783

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.1746
Qvap [kW] =	0.0764

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-20.99	-17.02	-14.63	-15.48	-6.788	-10.35	-21.77	-18.38	-16.11	-16.47	-8.4	-10.24
2	-20.92	-16.96	-14.55	-13.08	-2.498	-9.82	-21.03	-18.16	-16.03	-15.2	-7.86	-9.34
3	-20.83	-16.33	-13.8	-12.46	-6.037	-9	-20.76	-17.25	-15.02	-12.82	-7.74	-8.67
4	-20.79	-16.21	-13.7	-13.38	-6.198	-9.2	-20.76	-17.33	-14.98	-13.84	-7.88	-8.93
5	-20.81	-16.19	-13.75	-14.19	-6.837	-9.49	-20.95	-17.45	-15.18	-14.93	-8.07	-9.34
6	-20.84	-16.19	-13.87	-14.77	-6.796	-9.74	-21.3	-17.62	-15.48	-15.89	-8.17	-9.62
7	-20.89	-16.25	-13.99	-14.99	-6.748	-9.86	-21.26	-17.73	-15.65	-16.2	-8.23	-9.73
8	-20.91	-16.27	-14.09	-15.11	-6.723	-9.97	-21.27	-17.81	-15.77	-16.38	-8.26	-9.81
9	-20.92	-16.98	-14.55	-13.31	-2.183	-9.88	-21.09	-18.23	-16.06	-15.44	-7.89	-9.46
AV	-20.88	-16.49	-14.10	-14.09	-5.65	-9.70	-21.13	-17.77	-15.59	-15.24	-8.06	-9.46

Warmest Test Package	-5.65
Coldest Test Package	-21.13
Average Test Package	-14.01

Average values of data during last 3/4's of running cycle (SI)

DATE:	092396-1
MINUTES:	

MASS FLOW RATE	
mdot [g/s] =	5.52

PRESSURES	(Absolute)
Prin [kPa] =	1848.14
Prout [kPa] =	317.34

POWER USAGE	
W1 [W] =	310.10
W2 [W] =	-0.14

GENERAL TEMPERATURES	
Tref [°C] =	24.59
Tdb [°C] =	24.86
Twb [°C] =	18.44

SAT TEMP (Prout)	
Tsat [°C] =	-18.66

SUPERHEAT	
[°C] =	7.79

CASE INLET	
Trin [°C] =	27.66

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	23.17
HOT FLUID OUT	
Trhx-2 [°C] =	11.00

EVAPORATOR INLET	
Tri-1 [°C] =	-18.46
Tri-2 [°C] =	-18.55
Tri-3 [°C] =	-18.36
Tri av [°C] =	-18.46
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-18.08
Tr1-2 [°C] =	-17.95
Tr1-3 [°C] =	-17.97
Tr1 av [°C] =	-18.00
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-17.54
Tr2-2 [°C] =	-14.56
Tr2-3 [°C] =	-17.31
Tr2 av [°C] =	-16.47
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-16.93
Tr3-2 [°C] =	-13.15
Tr3-3 [°C] =	-14.53
Tr3 av [°C] =	-14.87
EVAPORATOR OUTLET	
Tro-1 [°C] =	-11.37
Tro-2 [°C] =	-11.59
Tro-3 [°C] =	-11.63
Tro av [°C] =	-11.53
XCHR: COLD FLUID IN	
Trex [°C] =	-10.87
Trhx-4 [°C] =	-7.60
COLD FLUID OUT	
Trhx-3 [°C] =	0.45

CASE OUTLET	
Trout [°C] =	1.69

PACKAGE TEMPERATURES	
P-1 [°C] =	-10.05
P-2 [°C] =	-2.38
P-3 [°C] =	-3.64
P-4 [°C] =	-14.65
P-5 [°C] =	-11.27
P-6 [°C] =	-9.28
P-7 [°C] =	-8.66
P-8 [°C] =	-0.68
P-9 [°C] =	-4.18
P-10 [°C] =	-14.01
P-11 [°C] =	-9.63
P-12 [°C] =	-7.75

CASE AIR: DELIVERED	
Tad-1 [°C] =	-15.33
Tad-2 [°C] =	-15.09
Tad-3 [°C] =	-13.79
Tad-4 [°C] =	-13.97
Tad av [°C] =	-14.54
CASE AIR: CENTER	
Tac-1 [°C] =	25.27
Tac-2 [°C] =	-9.11
Tac-3 [°C] =	-15.90

CASE AIR: RETURNED	
Tar-1 [°C] =	-9.71
Tar-2 [°C] =	-10.44
Tar-3 [°C] =	-10.10
Tar-4 [°C] =	-8.20
Tad av [°C] =	-9.61

h + hx-1	234.89
Qliq	0.1043

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	374.40
hl [kJ/kg] =	242.26
Qrt [kW] =	0.7289

EVAPORATOR LOAD	
ho [kJ/kg] =	363.31
hi [kJ/kg] =	216.00
Qevap [kW] =	0.8126

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.1449
Qvap [kW] =	0.0612

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-14.39	-9.78	-7.84	-9.02	-0.863	-4.298	-15.05	-11.31	-9.37	-10.32	-2.441	-3.615
2	-14.29	-9.8	-7.85	-7.33	5.212	-4.092	-14.36	-11.25	-9.37	-9.74	-0.499	-3.298
3	-13.29	-9.64	-7.72	-7.58	0.176	-4.006	-12.01	-10.79	-9.14	-8.53	-1.639	-3.319
4	-13.18	-9.53	-7.61	-7.79	-0.331	-3.9	-12.74	-10.78	-8.94	-8.64	-2.121	-3.312
5	-13.34	-9.52	-7.61	-8.07	-0.597	-3.935	-13.42	-10.88	-8.96	-9.08	-2.343	-3.368
6	-13.46	-9.51	-7.59	-8.21	-0.692	-3.939	-13.78	-10.91	-8.97	-9.36	-2.409	-3.35
7	-13.6	-9.52	-7.61	-8.34	-0.774	-4.006	-14.09	-10.97	-9.03	-9.59	-2.469	-3.417
8	-13.71	-9.55	-7.64	-8.43	-0.789	-4.073	-14.29	-11.03	-9.11	-9.75	-2.478	-3.46
9	-14.32	-9.8	-7.85	-7.29	5.718	-4.098	-14.57	-11.29	-9.38	-9.83	-0.488	-3.325
AV	-13.73	-9.63	-7.70	-8.01	0.78	-4.04	-13.81	-11.02	-9.14	-9.43	-1.88	-3.38

Warmest Test Package	0.78
Coldest Test Package	-13.81
Average Test Package	-7.58

Average values of data during last 3/4's of running cycle (SI)

DATE:	093096-1
MINUTES:	

MASS FLOW RATE	
mdot [g/s] =	4.48

PRESSURES	(Absolute)
Prin [kPa] =	1887.01
Prout [kPa] =	360.54

POWER USAGE	
W1 [W] =	306.97
W2 [W] =	0.15

GENERAL TEMPERATURES	
Tref [°C] =	24.90
Tdb [°C] =	25.31
Twb [°C] =	17.73

SAT TEMP (Prout)	
Tsat [°C] =	-15.15

SUPERHEAT	
[°C] =	12.35

CASE INLET	
Trin [°C] =	27.39

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	23.02
HOT FLUID OUT	
Trhx-2 [°C] =	13.29

EVAPORATOR INLET	
Tri-1 [°C] =	-14.96
Tri-2 [°C] =	-15.02
Tri-3 [°C] =	-14.78
Tri av [°C] =	-14.92
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-13.76
Tr1-2 [°C] =	-9.10
Tr1-3 [°C] =	-11.90
Tr1 av [°C] =	-11.58
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-6.16
Tr2-2 [°C] =	-5.74
Tr2-3 [°C] =	-5.44
Tr2 av [°C] =	-5.78
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-3.52
Tr3-2 [°C] =	-3.73
Tr3-3 [°C] =	-3.40
Tr3 av [°C] =	-3.55
EVAPORATOR OUTLET	
Tro-1 [°C] =	-2.66
Tro-2 [°C] =	-3.05
Tro-3 [°C] =	-3.35
Tro av [°C] =	-3.02
XCHR: COLD FLUID IN	
Trex [°C] =	-2.80
Trhx-4 [°C] =	0.28
COLD FLUID OUT	
Trhx-3 [°C] =	5.85

CASE OUTLET	
Trout [°C] =	7.04

PACKAGE TEMPERATURES	
P-1 [°C] =	-1.93
P-2 [°C] =	4.20
P-3 [°C] =	3.16
P-4 [°C] =	-5.98
P-5 [°C] =	-4.40
P-6 [°C] =	-2.88
P-7 [°C] =	-1.89
P-8 [°C] =	4.08
P-9 [°C] =	2.07
P-10 [°C] =	-7.20
P-11 [°C] =	-3.99
P-12 [°C] =	-1.71

CASE AIR: DELIVERED	
Tad-1 [°C] =	-8.90
Tad-2 [°C] =	-6.75
Tad-3 [°C] =	-7.05
Tad-4 [°C] =	-4.02
Tad av [°C] =	-6.68
CASE AIR: CENTER	
Tac-1 [°C] =	26.16
Tac-2 [°C] =	-1.22
Tac-3 [°C] =	-7.53

CASE AIR: RETURNED	
Tar-1 [°C] =	-2.75
Tar-2 [°C] =	-2.36
Tar-3 [°C] =	-2.28
Tar-4 [°C] =	0.03
Tar av [°C] =	-1.84

h fghx-1	234.63
Qliq	0.0676

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	378.40
hl [kJ/kg] =	241.82
Qrt [kW] =	0.6122

EVAPORATOR LOAD	
ho [kJ/kg] =	369.70
hi [kJ/kg] =	219.54
Qevap [kW] =	0.6730

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.0999
Qvap [kW] =	0.0390

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-7.29	-4.204	-2.152	-1.686	3.997	2.745	-6.144	-4.627	-3.121	-2.047	4.32	3.508
2	-7.32	-4.202	-2.098	1.029	8.45	3.551	-6.13	-4.605	-3.1	-0.855	5.622	4.979
3	-7.28	-4.184	-1.965	-1.559	5.023	3.833	-5.902	-4.558	-3.077	-1.508	4.834	4.646
4	-7.14	-4.142	-1.902	-1.7	4.803	3.26	-5.672	-4.491	-2.996	-1.776	4.477	4.018
5	-7.09	-4.125	-1.9	-1.801	4.692	2.868	-5.66	-4.478	-2.961	-1.883	4.306	3.643
6	-7.1	-4.13	-1.886	-1.863	4.57	2.559	-5.743	-4.507	-2.981	-1.948	4.196	3.418
7	-7.07	-4.089	-1.853	-1.868	4.549	2.364	-5.777	-4.465	-2.941	-1.94	4.183	3.343
8	-7.08	-4.084	-1.855	-1.888	4.478	2.205	-5.854	-4.487	-2.948	-1.945	4.156	3.261
9	-7.3	-4.186	-2.091	1.117	8.99	3.482	-6.121	-4.598	-3.092	-1.048	5.544	4.661
AV	-7.19	-4.15	-1.97	-1.14	5.51	2.99	-5.89	-4.54	-3.02	-1.66	4.63	3.94

Warmest Test Package	5.51
Coldest Test Package	-7.19
Average Test Package	-1.04

Average values of data during last 3/4's of running cycle (SI)

DATE:	
MINUTES:	11/19/96

MASS FLOW RATE	
mdot [g/s] =	8.09

PRESSURES	(Absolute)
Prin [kPa] =	1774.25
Prout [kPa] =	150.26

POWER USAGE	
W1 [W] =	309.46
W2 [W] =	-0.14

GENERAL TEMPERATURES	
Tref [°C] =	23.84
Tdb [°C] =	24.06
Twb [°C] =	17.04

SAT TEMP (Prout)	
Tsat [°C] =	-37.19

SUPERHEAT	
[°C] =	3.91

CASE INLET	
Trin [°C] =	26.26

XCHR: HOT FLUID IN	
Trhx-1 [°C] =	21.71
HOT FLUID OUT	
Trhx-2 [°C] =	0.56

EVAPORATOR INLET	
Tri-1 [°C] =	-36.71
Tri-2 [°C] =	-36.63
Tri-3 [°C] =	-36.39
Tri av [°C] =	-36.58
EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-35.65
Tr1-2 [°C] =	-35.95
Tr1-3 [°C] =	-35.88
Tr1 av [°C] =	-35.82
EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-33.79
Tr2-2 [°C] =	-34.77
Tr2-3 [°C] =	-34.76
Tr2 av [°C] =	-34.44
EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-32.10
Tr3-2 [°C] =	-33.05
Tr3-3 [°C] =	-33.48
Tr3 av [°C] =	-32.88
EVAPORATOR OUTLET	
Tro-1 [°C] =	-32.04
Tro-2 [°C] =	-32.32
Tro-3 [°C] =	-33.41
Tro av [°C] =	-32.59
XCHR: COLD FLUID IN	
Trex [°C] =	-33.28
Trhx-4 [°C] =	-32.87
COLD FLUID OUT	
Trhx-3 [°C] =	-19.07

CASE OUTLET	
Trout [°C] =	-19.68

PACKAGE TEMPERATURES	
P-1 [°C] =	-25.82
P-2 [°C] =	-15.61
P-3 [°C] =	-17.88
P-4 [°C] =	-30.28
P-5 [°C] =	-26.34
P-6 [°C] =	-24.28
P-7 [°C] =	-16.58
P-8 [°C] =	-15.83
P-9 [°C] =	-23.21
P-10 [°C] =	-29.81
P-11 [°C] =	-25.97
P-12 [°C] =	-21.84

CASE AIR: DELIVERED	
Tad-1 [°C] =	-30.57
Tad-2 [°C] =	-30.58
Tad-3 [°C] =	-29.28
Tad-4 [°C] =	-28.78
Tad av [°C] =	-29.80
CASE AIR: CENTER	
Tac-1 [°C] =	23.61
Tac-2 [°C] =	-23.21
Tac-3 [°C] =	-31.98

CASE AIR: RETURNED	
Tar-1 [°C] =	-21.17
Tar-2 [°C] =	-22.52
Tar-3 [°C] =	-24.65
Tar-4 [°C] =	-21.90
Tar av [°C] =	-22.56

h + rhx-1	232.57
Qliq	0.2571

Calculations (SI)

DISPLAY CASE LOAD	
hv [kJ/kg] =	362.84
hl [kJ/kg] =	239.94
Qrt [kW] =	0.9939

EVAPORATOR LOAD	
ho [kJ/kg] =	349.18
hi [kJ/kg] =	200.78
Qevap [kW] =	1.2001

HEAT EXCHANGER LOADS	
Qliq [kW] =	0.3167
Qvap [kW] =	0.1105

Package Temperatures (Based on ASHRAE Standard)

(Deg Celcius)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-30.52	-26.71	-22.11	-16.87	-16.33	-23.7	-31.54	-27.36	-25.04	-26.65	-16.22	-18.7
2	-27.82	-26.21	-21.85	-13.49	-12.71	-21.24	-27.34	-25.99	-23.94	-21.85	-14.84	-15.93
3	-25.22	-24.83	-20.99	-14.08	-13.18	-20.73	-24.97	-24.8	-21.81	-21.01	-14.36	-14.68
4	-26.77	-24.63	-20.92	-15.18	-14.06	-20.84	-27.33	-25.08	-22.29	-21.88	-14.77	-15.69
5	-27.85	-24.63	-21.03	-15.84	-14.68	-21.42	-28.44	-25.26	-22.74	-23.06	-15.02	-16.34
6	-28.64	-24.79	-21.21	-16.28	-15.18	-21.89	-29.33	-25.53	-23.31	-24.24	-15.26	-16.96
7	-29.13	-24.97	-21.39	-16.41	-15.43	-22.06	-29.86	-25.72	-23.75	-25.25	-15.33	-17.3
8	-29.42	-25.17	-21.56	-16.39	-15.5	-22.29	-30.07	-25.86	-23.98	-25.78	-15.41	-17.53
9	-26.48	-25.82	-21.67	-13.06	-12.45	-21	-25.72	-25.4	-23.24	-21.33	-14.48	-15.08
AV	-27.98	-25.31	-21.41	-15.29	-14.39	-21.69	-28.29	-25.67	-23.34	-23.45	-15.08	-16.47

Warmest Test Package	-14.39
Coldest Test Package	-28.29
Average Test Package	-21.53

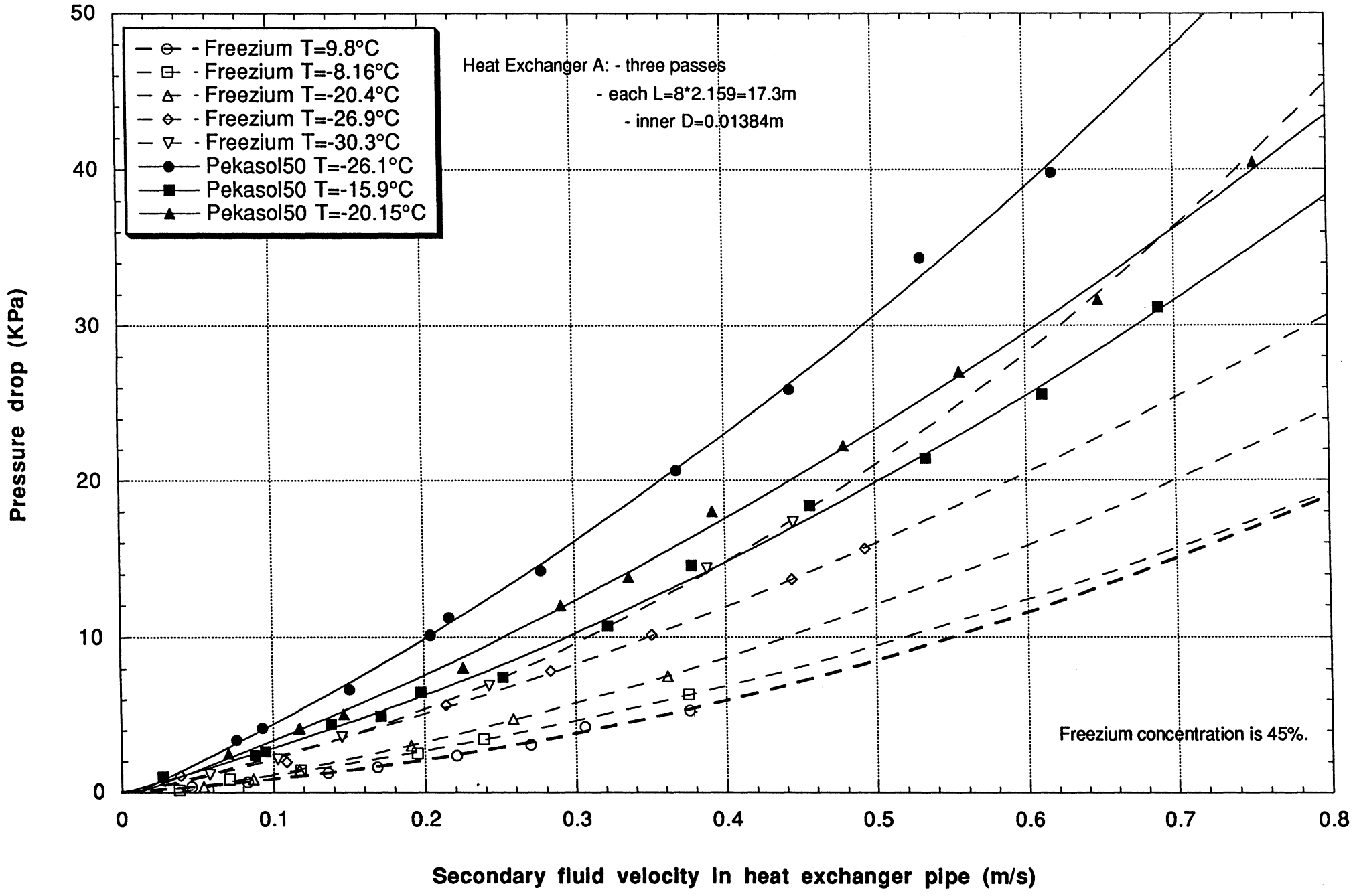
Appendix 2

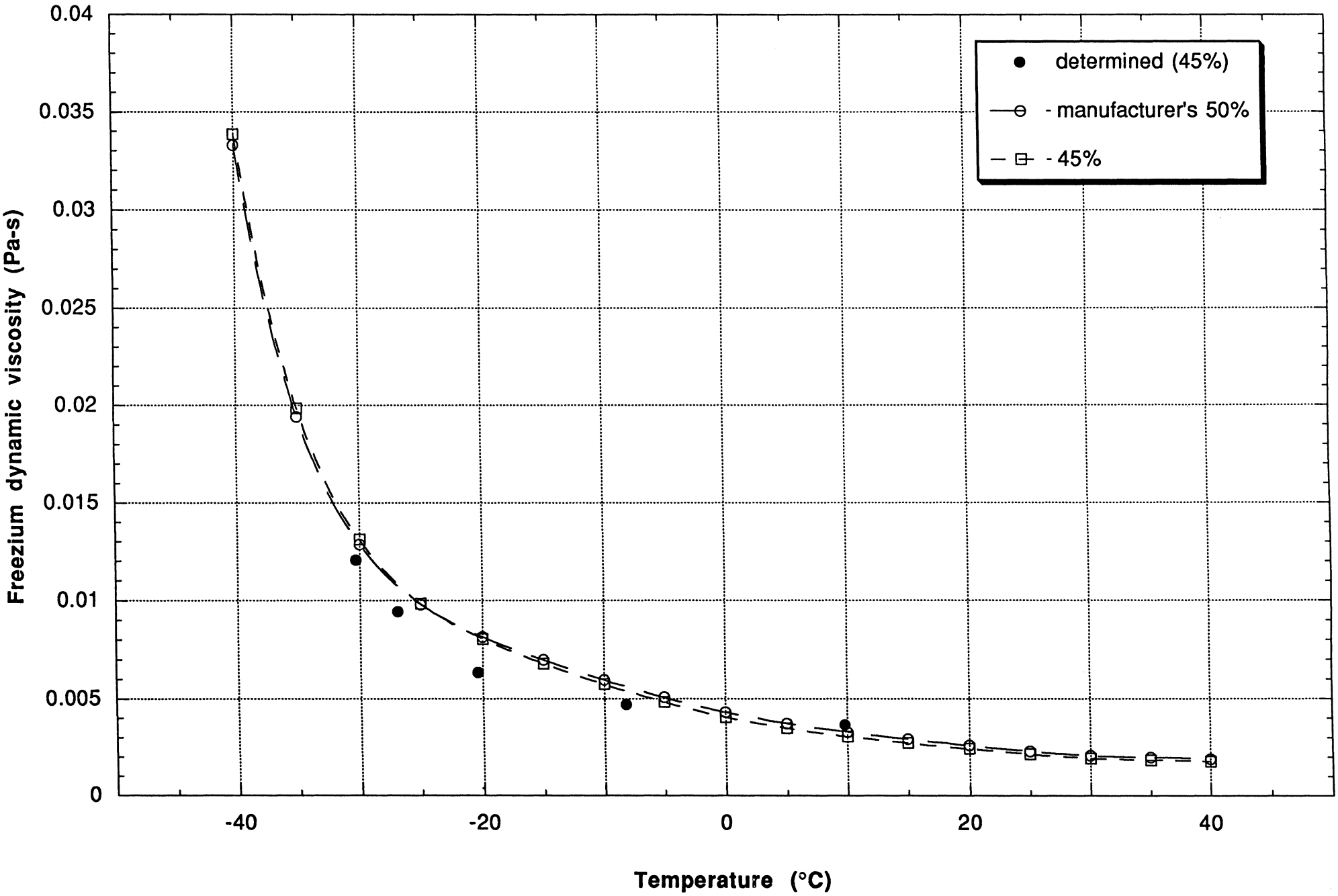
Freezium test data

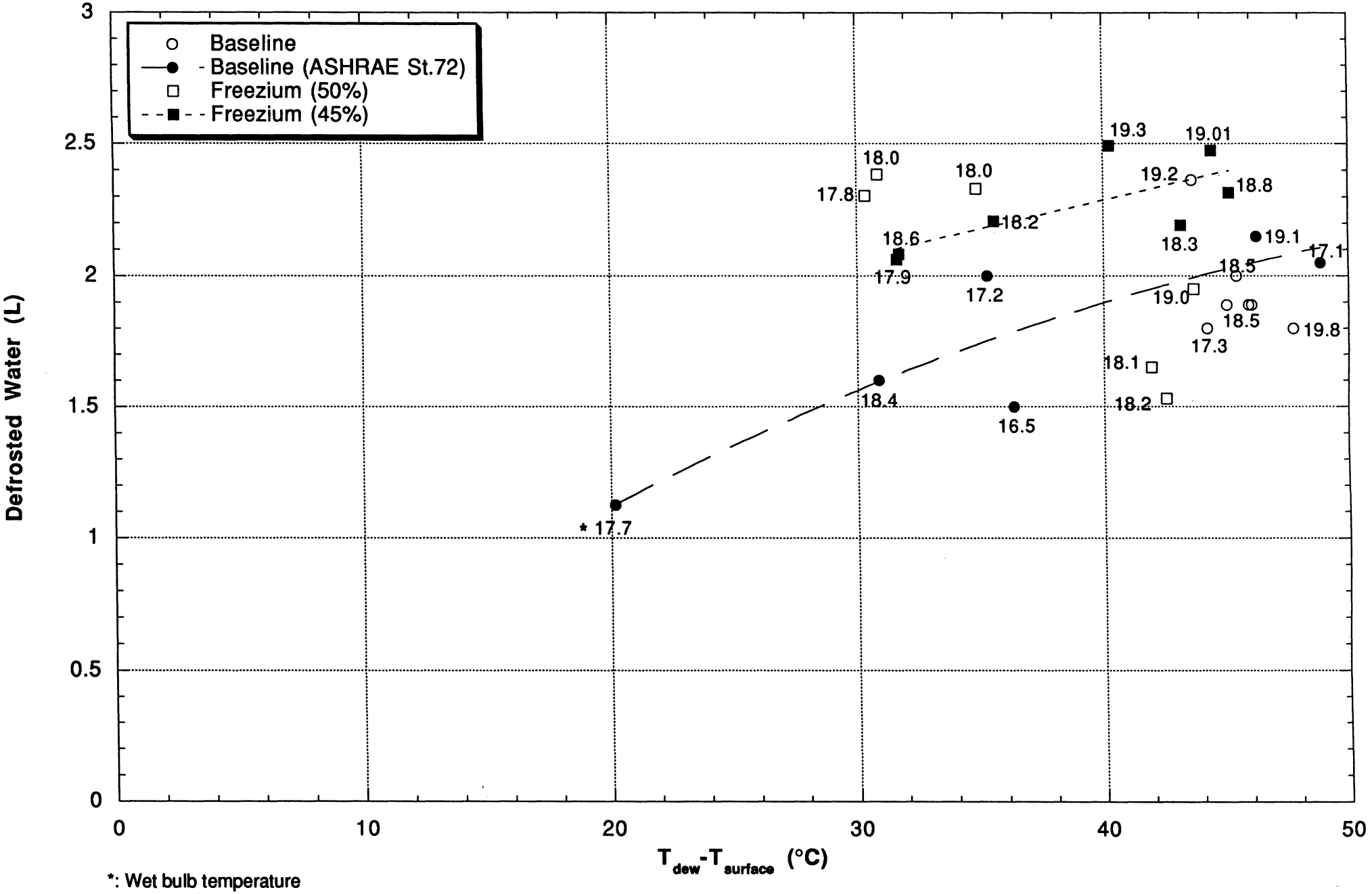
Table of Contents

Test Data Summary Table of Freezium 45%								
DATE	7/25/97	7/27/97	7/28/97	7/29/97	7/31/97	8/7/97	8/10/97	8/15/97
mdot [g/s] =	512.14	101.87	101.73	103.47	119.02	461.91	117.11	346.27
Pressures								
Prout [kPa] =	157.96	140.03	138.48	149.88	208.27	216.52	261.91	146.85
Power Usage								
W1 [kPa] =	296.86	716.28	299.66	302.72	304.44	303.6	302.94	303.16
General Temp								
Tref [°C] =	25.25	24.57	24.55	24.35	24.56	26.29	26.09	26.05
Tdb [°C] =	22.68	23.78	22.79	22.99	24.27	23.8	22.95	23.21
Twb [°C] =	19.01	18.37	18.77	18.31	18.24	17.91	18.65	19.29
Case Inlet								
Trin [°C] =	-27.71	-29.62	-29.79	-28.8	-22.05	-17.3	-16.44	-23.48
HX Inlet								
Tri-1 [°C] =	-27.37	-29.25	-29.49	-28.53	-21.86	-17.2	-16.24	-23.32
Tri-2 [°C] =	-27.54	-29.45	-29.67	-28.67	-21.98	-17.26	-16.35	-23.4
Tri-3 [°C] =	-27.47	-29.4	-29.6	-28.59	-21.89	-17.2	-16.18	-23.35
Tri av [°C] =	-27.46	-29.37	-29.58	-28.6	-21.91	-17.22	-16.26	-23.36
Pass 1								
Tr1-1 [°C] =	-27.03	-28.35	-28.64	-27.73	-21.31	-17.04	-15.75	-23.06
Tr1-2 [°C] =	-26.98	-28.05	-28.44	-27.5	-21.09	-16.84	-15.53	-22.79
Tr1-3 [°C] =	-27.21	-28.58	-28.77	-27.78	-21.29	-17	-15.7	-22.81
Tri av [°C] =	-27.07	-28.32	-28.62	-27.67	-21.23	-16.96	-15.66	-22.89
Pass 2								
Tr2-1 [°C] =	-27.13	-27.79	-28.02	-26.76	-20.88	-16.95	-15.34	-23.02
Tr2-2 [°C] =	-26.92	-27.43	-27.76	-26.74	-20.66	-16.76	-15.1	-22.76
Tr2-3 [°C] =	-26.94	-27.42	-27.74	-26.82	-20.58	-16.75	-15.08	-22.7
Tr2 av [°C] =	-26.99	-27.55	-27.84	-26.77	-20.7	-16.82	-15.17	-22.83
Pass 3								
Tr3-1 [°C] =	-26.69	-26.85	-27.2	-26.13	-20.22	-16.67	-14.78	-22.6
Tr3-2 [°C] =	-26.55	-26.57	-27.06	-26.25	-20.12	-16.56	-14.63	-22.47
Tr3-3 [°C] =	-26.86	-26.71	-27.2	-26.32	-20.13	-16.61	-14.53	-22.57
Tr3 av [°C] =	-26.7	-26.71	-27.15	-26.23	-20.16	-16.61	-14.65	-22.55
HX Outlet								
Tro-1 [°C] =	-26.04	-25.33	-26.13	-25.12	-19.05	-16.1	-13.79	-21.77
Tro-2 [°C] =	-26.06	-25.33	-26.11	-25.16	-19.1	-16.07	-13.85	-21.75
Tro-3 [°C] =	-26.16	-25.26	-25.96	-25.1	-18.99	-15.99	-13.78	-21.67
Tro av [°C] =	-26.09	-25.31	-26.07	-25.13	-19.05	-16.05	-13.81	-21.73
Case Outlet								
Trout [°C] =	-27.11	-26.84	-27.07	-26.07	-19.69	-16.73	-14.37	-22.63
Case Delivered								
Tad-1 [°C] =	-23.03	-22.57	-23.98	-23.29	-17.25	-12.2	-11.57	-18.69
Tad-2 [°C] =	-21.68	-22.35	-23.25	-22.95	-16.65	-13.14	-11.4	-18.48
Tad-3 [°C] =	-23.01	-21.79	-24.63	-23.45	-17.88	-14.85	-13.32	-20.47
Tad-4 [°C] =	-21.24	-13.99	-23.7	-22.8	-17.21	-15.31	-13.58	-20.9
Tad av [°C] =	-22.24	-20.18	-23.89	-23.12	-17.25	-13.87	-12.47	-19.63

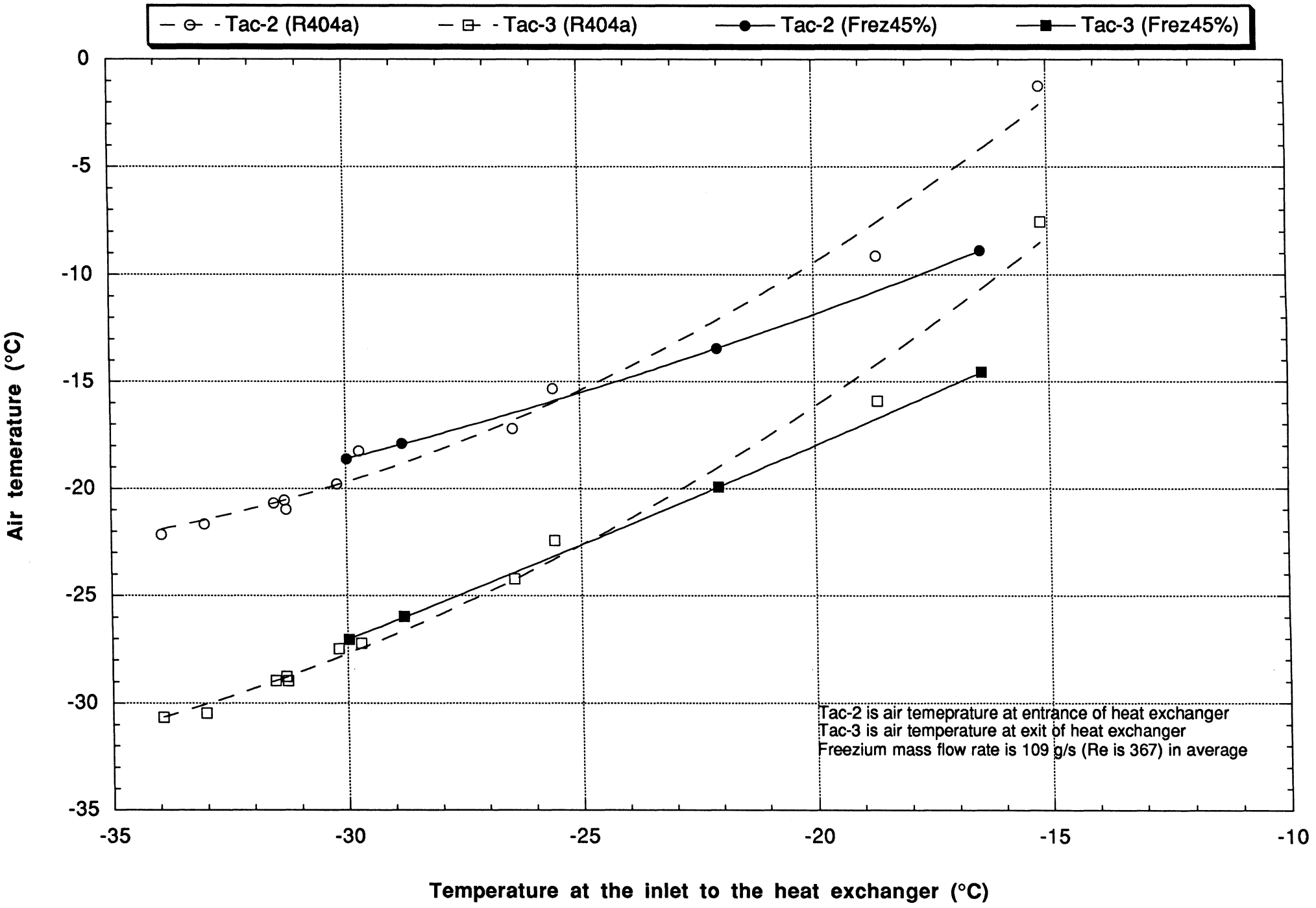
DATE	7/25/97	7/27/97	7/28/97	7/29/97	7/31/97	8/7/97	8/10/97	8/15/97
Case Center								
Tac-1 [°C] =	21.69	23.4	21.33	21.5	23.32	22.85	22.29	22.09
Tac-2 [°C] =	-16.99	-13.52	-18.61	-17.89	-13.43	-10.3	-8.86	-14.6
Tac-3 [°C] =	-26.25	-27.12	-27.04	-25.97	-19.93	-16.17	-14.53	-21.84
Case Returned								
Tar-1 [°C] =	-13.33	-12.87	-15.86	-16.07	-9.14	-6.33	-5.25	-10.41
Tar-2 [°C] =	-13.26	-11.77	-15.14	-14.88	-9.74	-7.31	-5.9	-11.43
Tar-3 [°C] =	-14.69	-10.31	-17.08	-16.55	-12.16	-9.37	-7.75	-14.6
Tar-4 [°C] =	-9.39	-2.07	-11.36	-8.59	-8.16	-5.82	-3.76	-9.45
Tar av [°C] =	-12.67	-9.26	-14.86	-14.02	-9.8	-7.21	-5.67	-11.47
HX Load								
Qref [kW] =	0.8763	0.8086	0.7908	0.8071	0.8026	0.7523	0.6898	0.8457
Defrost								
Tdef [°C] =	30.3	30	29.7	30.2	30	29.9	30.3	30
Time [min.] =	21	19	18	17	11	9.7	10	11
mdef [g/s] =	611	482	477	474	460	603	466	574
Water [L] =	2.47	3.165	2.316	2.193	2.207	2.062	2.08	2.493
Note: The dehumidifier was on when W1>300 W.								

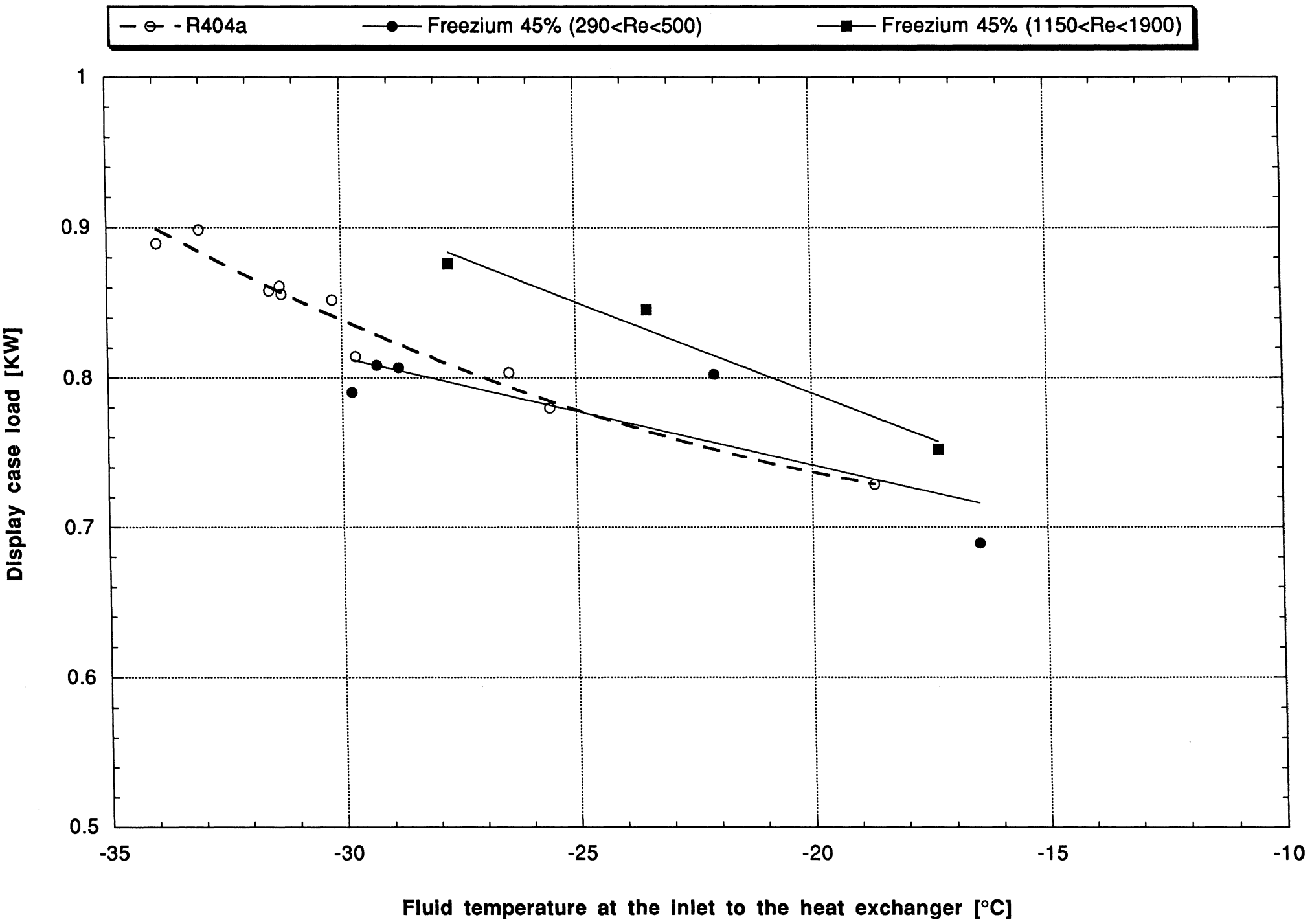

- Freezium T=9.8°C
- Freezium T=-8.16°C
- Freezium T=-20.4°C
- Freezium T=-26.9°C
- Freezium T=-30.3°C
Pekasol50 T=-26.1°C
Pekasol50 T=-15.9°C
Pekasol50 T=-20.15°C
Heat Exchanger A: - three passes
- each L=8*2.159=17.3m
- inner D=0.01384m
Freezium concentration is 45%.
Pressure drop (KPa)
Secondary fluid velocity in heat exchanger pipe (m/s)
0
10
20
30
40
50
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8


0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Freezium dynamic viscosity (Pa-s)
-40
-20
0
20
40
Temperature (°C)
determined (45%)
- manufacturer's 50%
- 45%



*: Wet bulb temperature


Tac-2 (R404a)
Tac-3 (R404a)
Tac-2 (Frez45%)
Tac-3 (Frez45%)
0
-5
-10
-15
-20
-25
-30
-35
-35
-30
-25
-20
-15
-10
Air temerature (°C)
Temperature at the inlet to the heat exchanger (°C)
Tac-2 is air temeprature at entrance of heat exchanger
Tac-3 is air temperature at exit of heat exchanger
Freezium mass flow rate is 109 g/s (Re is 367) in average


R404a
Freezium 45% (290<Re<500)
Freezium 45% (1150<Re<1900)
1
0.9
0.8
0.7
0.6
0.5
Display case load [KW]
-35
-30
-25
-20
-15
-10
Fluid temperature at the inlet to the heat exchanger [°C]

Average values of data during last 3/4's of running cycle (SI)

TYLER SECONDARY TEST (FLUID USED: Freezium 45%)

DATE:	7/27/97
MINUTES:	780

MASS FLOW RATE	
mdot2 [g/s] =	103.96

DIFF PRESSURE HX	
DPhx [kPa] =	

POWER USAGE	
W1 [W] =	715.52

GENERAL TEMPERATURES	
Tref [°C] =	24.56
Tdb [°C] =	23.78
Twb [°C] =	18.37

CASE INLET	
Trin [°C] =	-29.03

EVAPORATOR INLET	
Tri-1 [°C] =	-28.70
Tri-2 [°C] =	-28.87
Tri-3 [°C] =	-28.81
Tri av [°C] =	-28.79

EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-27.81
Tr1-2 [°C] =	-27.54
Tr1-3 [°C] =	-27.96
Tr1 av [°C] =	-27.77

EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-27.13
Tr2-2 [°C] =	-26.87
Tr2-3 [°C] =	-26.82
Tr2 av [°C] =	-26.94

EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-26.30
Tr3-2 [°C] =	-26.10
Tr3-3 [°C] =	-26.14
Tr3 av [°C] =	-26.18

EVAPORATOR OUTLET	
Tro-1 [°C] =	-24.87
Tro-2 [°C] =	-24.89
Tro-3 [°C] =	-24.77
Tro av [°C] =	-24.84

CASE OUTLET	
Trout [°C] =	-25.96

PACKAGE TEMPERATURES	
P-1 [°C] =	-18.98
P-2 [°C] =	-11.01
P-3 [°C] =	-12.35
P-4 [°C] =	-23.83
P-5 [°C] =	-19.09
P-6 [°C] =	-16.91
P-7 [°C] =	-23.67
P-8 [°C] =	-11.34
P-9 [°C] =	-11.25
P-10 [°C] =	-23.67
P-11 [°C] =	-21.31
P-12 [°C] =	-18.56

CASE AIR: DELIVERED	
Tad-1 [°C] =	-22.57
Tad-2 [°C] =	-22.35
Tad-3 [°C] =	-21.79
Tad-4 [°C] =	-13.99
Tad av [°C] =	-20.18

CASE AIR: CENTER	
Tac-1 [°C] =	22.98
Tac-2 [°C] =	-14.64
Tac-3 [°C] =	-25.98

CASE AIR: RETURNED	
Tar-1 [°C] =	-12.87
Tar-2 [°C] =	-11.77
Tar-3 [°C] =	-10.31
Tar-4 [°C] =	-2.07
Tar av [°C] =	-9.26

CHILLER SYSTEM

PRESSURES	*(Absolute)*
Prin [kPa] =	#DIV/0!
Prout [kPa] =	142.59

SAT TEMP (Prout)	
Tsat [°C] =	-37.90

2nd Fluid in System	
Tlin [°C] =	-25.95
Tlout [°C] =	-30.34
Tpumpin[C]=	-27.70
Tpumpout[C]=	-26.09

PLATE HX	
Txv1 [°C] =	25.69
Tpin1 [°C] =	#DIV/0!
Tpout1 [°C] =	#DIV/0!
Tsin1 [°C] =	#DIV/0!
Tsout1 [°C] =	#DIV/0!
SUPERHEAT	
[°C] =	#DIV/0!

SHELL & TUBE HX	
Txv1 [°C] =	25.69
Tpin2 [°C] =	-38.55
Tpout2 [°C] =	-29.59
Tsin2 [°C] =	-25.38
Tsout2 [°C] =	-35.12
SUPERHEAT	
[°C] =	8.31

Calculations (SI)

2ND FLUID PROPERTIES	
Temp =	-29.03
Density =	1315.93
Spec Heat =	2.86
Viscosity =	1.05E-02

TUBES IN HX	
ID [mm]=	13.84
Area [m^2]=	1.50E-04
Vdot [m^3/s]=	2.63E-05
Vel [m/s]=	0.175
Re [-]=	304.36

TUBES IN MAIN PIPE	
ID [mm]=	19.94
Area [m^2]=	3.12E-04
Vdot [m^3/s]=	7.90E-05
Vel [m/s]=	0.253
Re [-]=	633.75

HX LOAD	
Tavg [°C]=	-20.31
Cp air =	1.00
dT air [°C]=	11.33
dT fluid [°C]=	3.07
dT1 [°C]=	11.32
dT2 [°C]=	3.05
LMTD [°C]=	6.31
Qref [kW]=	0.9115
mair [kg/s]=	0.0800

Package Temperatures (°C) 07/27/97 Freezium 45%

(Based on ASHRAE Standard)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-25.72	-22.21	-19.61	-18.84	-12.03	-12.41	-26.31	-20.65	-18.79	-20.9	-11.78	-14.45
2	-21.69	-21.15	-18.77	-13.01	-10.51	-10.54	-21.37	-19.45	-17.81	-16.25	-10.24	-12.08
3	-21.71	-21.15	-18.42	-14.99	-10.66	-10.65	-21.51	-19.28	-17.29	-17.6	-10.42	-11.94
4	-22.3	-21.18	-18.41	-15.96	-10.93	-10.96	-22.01	-19.27	-17.15	-18.35	-10.73	-12.21
5	-22.77	-21.21	-18.44	-16.49	-11.12	-11.1	-22.6	-19.23	-17.09	-18.62	-10.9	-12.44
6	-23.1	-21.24	-18.47	-16.69	-11.23	-11.22	-23.07	-19.23	-17.07	-18.78	-11	-12.61
7	-23.29	-21.27	-18.49	-16.84	-11.3	-11.26	-23.31	-19.19	-17.04	-18.81	-11.04	-12.7
8	-23.49	-21.31	-18.53	-17.03	-11.33	-11.3	-23.53	-19.16	-17.01	-18.89	-11.07	-12.71
9	-21.69	-21.15	-18.77	-13.01	-10.51	-10.54	-21.37	-19.45	-17.81	-16.25	-10.24	-12.08
AV	-22.86	-21.32	-18.66	-15.87	-11.07	-11.11	-22.79	-19.43	-17.45	-18.27	-10.82	-12.58

Warmest Test Package	-10.82
Coldest Test Package	-22.86
Average Test Package	-16.85

Average values of data during last 3/4's of running cycle (SI)

TYLER SECONDARY TEST (FLUID USED: Freezium 45%)

DATE:	7/29/97
MINUTES:	1080

MASS FLOW RATE	
mdot2 [g/s] =	103.47

DIFF PRESSURE HX	
DPhx [kPa] =	

POWER USAGE	
W1 [W] =	302.72

GENERAL TEMPERATURES	
Tref [°C] =	24.35
Tdb [°C] =	22.99
Twb [°C] =	18.31

CASE INLET	
Trin [°C] =	-28.80

EVAPORATOR INLET	
Tri-1 [°C] =	-28.53
Tri-2 [°C] =	-28.67
Tri-3 [°C] =	-28.59
Tri av [°C] =	-28.60

EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-27.73
Tr1-2 [°C] =	-27.50
Tr1-3 [°C] =	-27.78
Tr1 av [°C] =	-27.67

EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-26.76
Tr2-2 [°C] =	-26.74
Tr2-3 [°C] =	-26.82
Tr2 av [°C] =	-26.77

EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-26.13
Tr3-2 [°C] =	-26.25
Tr3-3 [°C] =	-26.32
Tr3 av [°C] =	-26.23

EVAPORATOR OUTLET	
Tro-1 [°C] =	-25.12
Tro-2 [°C] =	-25.16
Tro-3 [°C] =	-25.10
Tro av [°C] =	-25.13

CASE OUTLET	
Trout [°C] =	-26.07

PACKAGE TEMPERATURES	
P-1 [°C] =	-19.72
P-2 [°C] =	-11.30
P-3 [°C] =	-13.91
P-4 [°C] =	-24.57
P-5 [°C] =	-19.97
P-6 [°C] =	-17.98
P-7 [°C] =	-24.43
P-8 [°C] =	-11.65
P-9 [°C] =	-12.47
P-10 [°C] =	-24.43
P-11 [°C] =	-21.71
P-12 [°C] =	-19.17

CASE AIR: DELIVERED	
Tad-1 [°C] =	-23.29
Tad-2 [°C] =	-22.95
Tad-3 [°C] =	-23.45
Tad-4 [°C] =	-22.80
Tad av [°C] =	-23.12

CASE AIR: CENTER	
Tac-1 [°C] =	21.50
Tac-2 [°C] =	-17.89
Tac-3 [°C] =	-25.97

CASE AIR: RETURNED	
Tar-1 [°C] =	-16.07
Tar-2 [°C] =	-14.88
Tar-3 [°C] =	-16.55
Tar-4 [°C] =	-8.59
Tar av [°C] =	-14.02

CHILLER SYSTEM

PRESSURES	*(Absolute)*
Prin [kPa] =	#DIV/0!
Prout [kPa] =	149.88

SAT TEMP (Prout)	
Tsat [°C] =	-36.91

2nd Fluid in System	
Tlin [°C] =	-26.09
Tlout [°C] =	-30.10
Tpumpin[C]=	-27.55
Tpumpout[C]=	-26.02

PLATE HX	
Txv1 [°C] =	32.53
Tpin1 [°C] =	#DIV/0!
Tpout1 [°C] =	#DIV/0!
Tsin1 [°C] =	#DIV/0!
Tsout1 [°C] =	#DIV/0!
SUPERHEAT	
[°C] =	#DIV/0!

SHELL & TUBE HX	
Txv1 [°C] =	32.53
Tpin2 [°C] =	-37.34
Tpout2 [°C] =	-29.50
Tsin2 [°C] =	-25.52
Tsout2 [°C] =	-34.49
SUPERHEAT	
[°C] =	7.41

Calculations (SI)

2ND FLUID PROPERTIES	
Temp =	-28.80
Density =	1315.73
Spec Heat =	2.86
Viscosity =	1.04E-02

TUBES IN HX	
ID [mm]=	13.84
Area [m^2]=	1.50E-04
Vdot [m^3/s]=	2.62E-05
Vel [m/s]=	0.174
Re [-]=	305.33

TUBES IN MAIN PIPE	
ID [mm]=	19.94
Area [m^2]=	3.12E-04
Vdot [m^3/s]=	7.86E-05
Vel [m/s]=	0.252
Re [-]=	635.77

HX LOAD	
Tavg [°C]=	-21.93
Cp air =	1.00
dT air [°C]=	8.08
dT fluid [°C]=	2.73
dT1 [°C]=	8.18
dT2 [°C]=	2.83
LMTD [°C]=	5.04
Qref [kW]=	0.8071
mair [kg/s]=	0.0994

Package Temperatures (°C) 07/29/97 Freezium 45%

(Based on ASHRAE Standard)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-25.49	-22.2	-19.56	-17.36	-12.13	-12.6	-25.96	-20.6	-18.65	-20.49	-11.1	-14.12
2	-22.69	-21.3	-19.37	-11.83	-10.91	-11.43	-22.41	-20.12	-18.42	-16.2	-10.3	-12.99
3	-21.62	-21.16	-18.51	-13.35	-10.55	-10.82	-21.53	-19.5	-17.52	-16.22	-9.87	-11.98
4	-21.81	-21.03	-18.35	-14.22	-10.68	-10.89	-21.67	-19.3	-17.16	-17	-9.9	-12.05
5	-22.33	-21.09	-18.45	-14.88	-10.92	-11.31	-22.22	-19.5	-17.33	-17.8	-10.28	-12.53
6	-22.65	-21.05	-18.44	-15.23	-11.01	-11.38	-22.68	-19.41	-17.29	-18.13	-10.31	-12.71
7	-22.99	-21.1	-18.5	-15.52	-11.1	-11.51	-23.1	-19.41	-17.32	-18.42	-10.4	-12.91
8	-23.27	-21.18	-18.57	-15.74	-11.17	-11.66	-23.43	-19.45	-17.42	-18.66	-10.52	-13.12
9	-21.87	-21.15	-18.85	-12.06	-10.56	-10.8	-21.55	-19.54	-17.86	-15.34	-9.84	-12.15
AV	-22.75	-21.25	-18.73	-14.47	-11.00	-11.38	-22.73	-19.65	-17.66	-17.58	-10.28	-12.73

Warmest Test Package	-10.28
Coldest Test Package	-22.75
Average Test Package	-16.68

Average values of data during last 3/4's of running cycle (SI)

TYLER SECONDARY TEST (FLUID USED: Freezium 45%)

DATE:	7/31/97
MINUTES:	1080

MASS FLOW RATE	
mdot2 [g/s] =	119.02

DIFF PRESSURE HX	
DPhx [kPa] =	

POWER USAGE	
W1 [W] =	304.44

GENERAL TEMPERATURES	
Tref [°C] =	24.56
Tdb [°C] =	24.27
Twb [°C] =	18.24

CASE INLET	
Trin [°C] =	-22.05

EVAPORATOR INLET	
Tri-1 [°C] =	-21.86
Tri-2 [°C] =	-21.98
Tri-3 [°C] =	-21.89
Tri av [°C] =	-21.91

EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-21.31
Tr1-2 [°C] =	-21.09
Tr1-3 [°C] =	-21.29
Tr1 av [°C] =	-21.23

EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-20.88
Tr2-2 [°C] =	-20.66
Tr2-3 [°C] =	-20.58
Tr2 av [°C] =	-20.70

EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-20.22
Tr3-2 [°C] =	-20.12
Tr3-3 [°C] =	-20.13
Tr3 av [°C] =	-20.16

EVAPORATOR OUTLET	
Tro-1 [°C] =	-19.05
Tro-2 [°C] =	-19.10
Tro-3 [°C] =	-18.99
Tro av [°C] =	-19.05

CASE OUTLET	
Trout [°C] =	-19.69

PACKAGE TEMPERATURES	
P-1 [°C] =	-13.83
P-2 [°C] =	-7.16
P-3 [°C] =	-8.90
P-4 [°C] =	-20.09
P-5 [°C] =	-16.14
P-6 [°C] =	-13.77
P-7 [°C] =	-20.22
P-8 [°C] =	-7.69
P-9 [°C] =	-7.80
P-10 [°C] =	-20.22
P-11 [°C] =	-18.19
P-12 [°C] =	-14.62

CASE AIR: DELIVERED	
Tad-1 [°C] =	-17.25
Tad-2 [°C] =	-16.65
Tad-3 [°C] =	-17.88
Tad-4 [°C] =	-17.21
Tad av [°C] =	-17.25

CASE AIR: CENTER	
Tac-1 [°C] =	23.32
Tac-2 [°C] =	-13.43
Tac-3 [°C] =	-19.93

CASE AIR: RETURNED	
Tar-1 [°C] =	-9.14
Tar-2 [°C] =	-9.74
Tar-3 [°C] =	-12.16
Tar-4 [°C] =	-8.16
Tar av [°C] =	-9.80

CHILLER SYSTEM

PRESSURES	*(Absolute)*
Prin [kPa] =	213.18
Prout [kPa] =	208.27

SAT TEMP (Prout)	
Tsat [°C] =	-29.54

2nd Fluid in System	
Tlin [°C] =	-19.93
Tlout [°C] =	-23.11
Tpumpin[C]=	-21.07
Tpumpout[C]=	-19.72

PLATE HX	
Txv1 [°C] =	28.52
Tpin1 [°C] =	#DIV/0!
Tpout1 [°C] =	#DIV/0!
Tsin1 [°C] =	#DIV/0!
Tsout1 [°C] =	#DIV/0!
SUPERHEAT	
[°C] =	#DIV/0!

SHELL & TUBE HX	
Txv1 [°C] =	28.52
Tpin2 [°C] =	-29.70
Tpout2 [°C] =	-22.10
Tsin2 [°C] =	-19.44
Tsout2 [°C] =	-26.60
SUPERHEAT	
[°C] =	7.44

Calculations (SI)

2ND FLUID PROPERTIES	
Temp =	-22.05
Density =	1310.28
Spec Heat =	2.85
Viscosity =	8.42E-03

TUBES IN HX	
ID [mm]=	13.84
Area [m^2]=	1.50E-04
Vdot [m^3/s]=	3.03E-05
Vel [m/s]=	0.201
Re [-]=	433.33

TUBES IN MAIN PIPE	
ID [mm]=	19.94
Area [m^2]=	3.12E-04
Vdot [m^3/s]=	9.08E-05
Vel [m/s]=	0.291
Re [-]=	902.31

HX LOAD	
Tavg [°C]=	-16.68
Cp air =	1.01
dT air [°C]=	6.50
dT fluid [°C]=	2.36
dT1 [°C]=	6.26
dT2 [°C]=	2.13
LMTD [°C]=	3.83
Qref [kW]=	0.8026
mair [kg/s]=	0.1229

Package Temperatures (°C) 07/31/97 Freezium45%

(Based on ASHRAE Standard)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-20.98	-19.74	-16.58	-11.6	-9.34	-9.62	-20.92	-17.74	-15.45	-14.79	-9.02	-10.64
2	-20.91	-19.06	-16.29	-8.46	-8.62	-8.91	-20.79	-17.28	-15.04	-12.76	-8.35	-10.04
3	-20.91	-18.95	-15.55	-9.11	-8.19	-8.27	-20.84	-16.69	-14.47	-11.68	-7.97	-9.15
4	-20.8	-19.01	-15.34	-9.98	-8.09	-8.09	-20.68	-16.56	-14.1	-12.33	-7.83	-9
5	-20.77	-18.95	-15.24	-10.39	-8.11	-8.11	-20.64	-16.53	-14.01	-12.73	-7.84	-9.05
6	-20.73	-18.88	-15.14	-10.61	-8.1	-8.09	-20.58	-16.48	-13.92	-12.97	-7.81	-9.04
7	-20.66	-18.77	-15.01	-10.72	-8.04	-7.99	-20.46	-16.36	-13.79	-13.07	-7.7	-8.96
8	-20.51	-18.57	-14.8	-10.67	-7.89	-7.71	-20.12	-16.03	-13.47	-12.93	-7.39	-8.67
9	-20.57	-18.79	-15.17	-9.42	-7.83	-7.64	-20.27	-16.11	-13.75	-11.54	-7.4	-8.59
AV	-20.76	-18.97	-15.46	-10.11	-8.25	-8.27	-20.59	-16.64	-14.22	-12.76	-7.92	-9.24

Warmest Test Package	-7.92
Coldest Test Package	-20.76
Average Test Package	-13.60

Average values of data during last 3/4's of running cycle (SI)

TYLER SECONDARY TEST (FLUID USED: Freezium 45%)

DATE:	8/7/97
MINUTES:	1080

MASS FLOW RATE	
mdot2 [g/s] =	461.91

DIFF PRESSURE HX	
DPhx [kPa] =	

POWER USAGE	
W1 [W] =	303.60

GENERAL TEMPERATURES	
Tref [°C] =	26.29
Tdb [°C] =	23.80
Twb [°C] =	17.91

CASE INLET	
Trin [°C] =	-17.30

EVAPORATOR INLET	
Tri-1 [°C] =	-17.20
Tri-2 [°C] =	-17.26
Tri-3 [°C] =	-17.20
Tri av [°C] =	-17.22

EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-17.04
Tr1-2 [°C] =	-16.84
Tr1-3 [°C] =	-17.00
Tr1 av [°C] =	-16.96

EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-16.95
Tr2-2 [°C] =	-16.76
Tr2-3 [°C] =	-16.75
Tr2 av [°C] =	-16.82

EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-16.67
Tr3-2 [°C] =	-16.56
Tr3-3 [°C] =	-16.61
Tr3 av [°C] =	-16.61

EVAPORATOR OUTLET	
Tro-1 [°C] =	-16.10
Tro-2 [°C] =	-16.07
Tro-3 [°C] =	-15.99
Tro av [°C] =	-16.05

CASE OUTLET	
Trout [°C] =	-16.73

PACKAGE TEMPERATURES	
P-1 [°C] =	-10.90
P-2 [°C] =	-4.45
P-3 [°C] =	-5.96
P-4 [°C] =	-15.25
P-5 [°C] =	-12.20
P-6 [°C] =	-10.37
P-7 [°C] =	-14.89
P-8 [°C] =	-4.22
P-9 [°C] =	-4.61
P-10 [°C] =	-14.89
P-11 [°C] =	-13.35
P-12 [°C] =	-10.71

CASE AIR: DELIVERED	
Tad-1 [°C] =	-12.20
Tad-2 [°C] =	-13.14
Tad-3 [°C] =	-14.85
Tad-4 [°C] =	-15.31
Tad av [°C] =	-13.87

CASE AIR: CENTER	
Tac-1 [°C] =	22.85
Tac-2 [°C] =	-10.30
Tac-3 [°C] =	-16.17

CASE AIR: RETURNED	
Tar-1 [°C] =	-6.33
Tar-2 [°C] =	-7.31
Tar-3 [°C] =	-9.37
Tar-4 [°C] =	-5.82
Tar av [°C] =	-7.21

CHILLER SYSTEM

PRESSURES	*(Absolute)*
Prin [kPa] =	#DIV/0!
Prout [kPa] =	216.52

SAT TEMP (Prout)	
Tsat [°C] =	-28.58

2nd Fluid in System	
Tlin [°C] =	-17.24
Tlout [°C] =	-18.05
Tpumpin[C]=	-16.42
Tpumpout[C]=	-15.11

PLATE HX	
Txv1 [°C] =	29.77
Tpin1 [°C] =	#DIV/0!
Tpout1 [°C] =	#DIV/0!
Tsin1 [°C] =	#DIV/0!
Tsout1 [°C] =	#DIV/0!
SUPERHEAT	
[°C] =	#DIV/0!

SHELL & TUBE HX	
Txv1 [°C] =	29.77
Tpin2 [°C] =	-28.68
Tpout2 [°C] =	-17.90
Tsin2 [°C] =	-16.94
Tsout2 [°C] =	-18.74
SUPERHEAT	
[°C] =	10.68

Calculations (SI)

2ND FLUID PROPERTIES	
Temp =	-17.30
Density =	1306.76
Spec Heat =	2.85
Viscosity =	7.39E-03

TUBES IN HX	
ID [mm]=	13.84
Area [m^2]=	1.50E-04
Vdot [m^3/s]=	1.18E-04
Vel [m/s]=	0.783
Re [-]=	1916.05

TUBES IN MAIN PIPE	
ID [mm]=	19.94
Area [m^2]=	3.12E-04
Vdot [m^3/s]=	3.53E-04
Vel [m/s]=	1.132
Re [-]=	3989.68

HX LOAD	
Tavg [°C]=	-13.23
Cp air =	1.01
dT air [°C]=	5.87
dT fluid [°C]=	0.57
dT1 [°C]=	6.43
dT2 [°C]=	1.13
LMTD [°C]=	3.05
Qref [kW]=	0.7523
mair [kg/s]=	0.1275

Package Temperatures (°C) 08/07/97 Freezium 45%

(Based on ASHRAE Standard)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-15.94	-14.21	-11.5	-8.55	-4.556	-5.242	-16.19	-13.01	-11.18	-11.72	-4.953	-6.734
2	-15.22	-13.76	-11.32	-6.957	-4.195	-4.963	-14.84	-12.59	-10.95	-10.09	-4.725	-6.371
3	-14.7	-13.6	-10.95	-7.23	-3.972	-4.457	-14.35	-12.11	-10.37	-9.78	-4.289	-5.788
4	-14.82	-13.74	-11.06	-7.6	-4.149	-4.733	-14.79	-12.45	-10.62	-10.36	-4.623	-6.112
5	-14.67	-13.56	-10.89	-7.57	-4.009	-4.516	-14.66	-12.24	-10.39	-10.28	-4.421	-5.949
6	-14.7	-13.61	-10.94	-7.67	-4.155	-4.644	-14.79	-12.37	-10.51	-10.48	-4.555	-6.055
7	-14.65	-13.54	-10.89	-7.67	-4.135	-4.606	-14.78	-12.29	-10.45	-10.46	-4.534	-5.998
8	-14.6	-13.47	-10.83	-7.67	-4.124	-4.58	-14.77	-12.24	-10.39	-10.46	-4.48	-5.96
9	-14.7	-13.6	-10.95	-7.23	-3.972	-4.457	-14.35	-12.11	-10.37	-9.78	-4.289	-5.788
AV	-14.89	-13.68	-11.04	-7.57	-4.14	-4.69	-14.84	-12.38	-10.58	-10.38	-4.54	-6.08

Warmest Test Package	-4.14
Coldest Test Package	-14.89
Average Test Package	-9.57

Average values of data during last 3/4's of running cycle (SI)

TYLER SECONDARY TEST (FLUID USED: Freezium 45%)

DATE:	8/10/97
MINUTES:	1080

MASS FLOW RATE	
mdot2 [g/s] =	117.11

DIFF PRESSURE HX	
DPhx [kPa] =	

POWER USAGE	
W1 [W] =	302.94

GENERAL TEMPERATURES	
Tref [°C] =	26.09
Tdb [°C] =	22.95
Twb [°C] =	18.65

CASE INLET	
Trin [°C] =	-16.44

EVAPORATOR INLET	
Tri-1 [°C] =	-16.24
Tri-2 [°C] =	-16.35
Tri-3 [°C] =	-16.18
Tri av [°C] =	-16.26

EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-15.75
Tr1-2 [°C] =	-15.53
Tr1-3 [°C] =	-15.70
Tr1 av [°C] =	-15.66

EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-15.34
Tr2-2 [°C] =	-15.10
Tr2-3 [°C] =	-15.08
Tr2 av [°C] =	-15.17

EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-14.78
Tr3-2 [°C] =	-14.63
Tr3-3 [°C] =	-14.53
Tr3 av [°C] =	-14.65

EVAPORATOR OUTLET	
Tro-1 [°C] =	-13.79
Tro-2 [°C] =	-13.85
Tro-3 [°C] =	-13.78
Tro av [°C] =	-13.81

CASE OUTLET	
Trout [°C] =	-14.37

PACKAGE TEMPERATURES	
P-1 [°C] =	-9.60
P-2 [°C] =	-4.50
P-3 [°C] =	-5.84
P-4 [°C] =	-13.85
P-5 [°C] =	-12.00
P-6 [°C] =	-10.24
P-7 [°C] =	-13.98
P-8 [°C] =	-4.00
P-9 [°C] =	-4.52
P-10 [°C] =	-13.98
P-11 [°C] =	-13.37
P-12 [°C] =	-10.82

CASE AIR: DELIVERED	
Tad-1 [°C] =	-11.57
Tad-2 [°C] =	-11.40
Tad-3 [°C] =	-13.32
Tad-4 [°C] =	-13.58
Tad av [°C] =	-12.47

CASE AIR: CENTER	
Tac-1 [°C] =	22.29
Tac-2 [°C] =	-8.86
Tac-3 [°C] =	-14.53

CASE AIR: RETURNED	
Tar-1 [°C] =	-5.25
Tar-2 [°C] =	-5.90
Tar-3 [°C] =	-7.75
Tar-4 [°C] =	-3.76
Tar av [°C] =	-5.67

CHILLER SYSTEM

PRESSURES	*(Absolute)*
Prin [kPa] =	#DIV/0!
Prout [kPa] =	261.91

SAT TEMP (Prout)	
Tsat [°C] =	-23.68

2nd Fluid in System	
Tlin [°C] =	-14.54
Tlout [°C] =	-17.47
Tpumpin[C]=	-15.68
Tpumpout[C]=	-14.53

PLATE HX	
Txv1 [°C] =	31.89
Tpin1 [°C] =	#DIV/0!
Tpout1 [°C] =	#DIV/0!
Tsin1 [°C] =	#DIV/0!
Tsout1 [°C] =	#DIV/0!
SUPERHEAT	
[°C] =	#DIV/0!

SHELL & TUBE HX	
Txv1 [°C] =	31.89
Tpin2 [°C] =	-24.09
Tpout2 [°C] =	-16.86
Tsin2 [°C] =	-14.06
Tsout2 [°C] =	-18.03
SUPERHEAT	
[°C] =	6.83

Calculations (SI)

2ND FLUID PROPERTIES	
Temp =	-16.44
Density =	1306.15
Spec Heat =	2.85
Dynamic Visco	7.13E-03

TUBES IN HX	
ID [mm]=	13.84
Area [m^2]=	1.50E-04
Vdot [m^3/s]=	2.99E-05
Vel [m/s]=	0.199
Re [-]=	503.54

TUBES IN MAIN PIPE	
ID [mm]=	19.94
Area [m^2]=	3.12E-04
Vdot [m^3/s]=	8.97E-05
Vel [m/s]=	0.287
Re [-]=	1048.50

HX LOAD	
Tavg [°C]=	-11.70
Cp air =	1.01
dT air [°C]=	5.67
dT fluid [°C]=	2.07
dT1 [°C]=	5.51
dT2 [°C]=	1.91
LMTD [°C]=	3.40
Qref [kW]=	0.6898
mair [kg/s]=	0.1210

Package Temperatures (°C) 08/10/97 Freezium45%

(Based on ASHRAE Standard)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-16.58	-15.3	-12.32	-7.06	-4.26	-5.323	-15.44	-13.41	-11.89	-9.63	-4.816	-6.74
2	-14.07	-12.82	-10.38	-7.38	-4.062	-4.446	-14.26	-11.63	-9.89	-10.01	-4.447	-5.636
3	-16.24	-15.23	-12.17	-7.25	-4.172	-5.179	-15.29	-13.38	-11.7	-9.71	-4.704	-6.614
4	-15.82	-14.98	-11.92	-7.19	-3.933	-4.786	-14.9	-13.02	-11.27	-9.49	-4.372	-6.286
5	-15.52	-14.92	-11.94	-7.36	-4.056	-5.02	-14.92	-13.24	-11.41	-9.83	-4.644	-6.532
6	-15.05	-14.68	-11.76	-7.21	-4.004	-4.906	-14.52	-13.06	-11.18	-9.64	-4.582	-6.398
7	-14.67	-14.42	-11.61	-7.08	-3.97	-4.817	-14.15	-12.86	-11	-9.45	-4.552	-6.282
8	-14.36	-14.22	-11.44	-7.02	-3.947	-4.73	-13.89	-12.71	-10.82	-9.31	-4.536	-6.165
9	-15.82	-14.98	-11.92	-7.19	-3.933	-4.786	-14.9	-13.02	-11.27	-9.49	-4.372	-6.286
AV	-15.35	-14.62	-11.72	-7.19	-4.04	-4.89	-14.70	-12.93	-11.16	-9.62	-4.56	-6.33

Warmest Test Package	-4.04
Coldest Test Package	-15.35
Average Test Package	-9.76

Average values of data during last 3/4's of running cycle (SI)

TYLER SECONDARY TEST (FLUID USED: Freezium 45%)

DATE:	8/15/97
MINUTES:	1080

MASS FLOW RATE	
mdot2 [g/s] =	346.27

DIFF PRESSURE HX	
DPhx [kPa] =	

POWER USAGE	
W1 [W] =	303.16

GENERAL TEMPERATURES	
Tref [°C] =	26.05
Tdb [°C] =	23.21
Twb [°C] =	19.29
Water (L) =	2.493

CASE INLET	
Trin [°C] =	-23.48

EVAPORATOR INLET	
Tri-1 [°C] =	-23.32
Tri-2 [°C] =	-23.40
Tri-3 [°C] =	-23.35
Tri av [°C] =	-23.36

EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-23.06
Tr1-2 [°C] =	-22.79
Tr1-3 [°C] =	-22.81
Tr1 av [°C] =	-22.89

EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-23.02
Tr2-2 [°C] =	-22.76
Tr2-3 [°C] =	-22.70
Tr2 av [°C] =	-22.83

EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-22.60
Tr3-2 [°C] =	-22.47
Tr3-3 [°C] =	-22.57
Tr3 av [°C] =	-22.55

EVAPORATOR OUTLET	
Tro-1 [°C] =	-21.77
Tro-2 [°C] =	-21.75
Tro-3 [°C] =	-21.67
Tro av [°C] =	-21.73

CASE OUTLET	
Trout [°C] =	-22.63

PACKAGE TEMPERATURES	
P-1 [°C] =	-16.28
P-2 [°C] =	-7.62
P-3 [°C] =	-9.54
P-4 [°C] =	-20.87
P-5 [°C] =	-16.31
P-6 [°C] =	-14.12
P-7 [°C] =	-20.52
P-8 [°C] =	-6.23
P-9 [°C] =	-7.48
P-10 [°C] =	-20.52
P-11 [°C] =	-17.87
P-12 [°C] =	-14.51
Paverage[°C]=	-14.32

CASE AIR: DELIVERED	
Tad-1 [°C] =	-18.69
Tad-2 [°C] =	-18.48
Tad-3 [°C] =	-20.47
Tad-4 [°C] =	-20.90
Tad av [°C] =	-19.63

CASE AIR: CENTER	
Tac-1 [°C] =	22.09
Tac-2 [°C] =	-14.60
Tac-3 [°C] =	-21.84

CASE AIR: RETURNED	
Tar-1 [°C] =	-10.41
Tar-2 [°C] =	-11.43
Tar-3 [°C] =	-14.60
Tar-4 [°C] =	-9.45
Tar av [°C] =	-11.47

CHILLER SYSTEM

PRESSURES	*(Absolute)*
Prin [kPa] =	
Prout [kPa] =	164.85

SAT TEMP (Prout)	
Tsat [°C] =	-34.92

2nd Fluid in System	
Tlin [°C] =	-23.10
Tlout [°C] =	-24.34
Tpumpin[C]=	-21.77
Tpumpout[C]=	-19.72

PLATE HX	
Txv1 [°C] =	24.13
Tpin1 [°C] =	
Tpout1 [°C] =	
Tsin1 [°C] =	
Tsout1 [°C] =	
SUPERHEAT	
[°C] =	

SHELL & TUBE HX	
Txv1 [°C] =	24.13
Tpin2 [°C] =	-35.30
Tpout2 [°C] =	-24.09
Tsin2 [°C] =	-22.72
Tsout2 [°C] =	-25.74
SUPERHEAT	
[°C] =	10.83

Calculations (SI)

2ND FLUID PROPERTIES	
Temp =	-23.48
Density =	1311.39
Spec Heat =	2.86
Dynamic Visco	9.22E-03

TUBES IN HX	
ID [mm]=	13.84
Area [m^2]=	1.50E-04
Vdot [m^3/s]=	8.80E-05
Vel [m/s]=	0.585
Re [-]=	1151.28

TUBES IN MAIN PIPE	
ID [mm]=	19.94
Area [m^2]=	3.12E-04
Vdot [m^3/s]=	2.64E-04
Vel [m/s]=	0.846
Re [-]=	2397.26

HX LOAD	
Tavg [°C]=	-18.22
Cp air =	1.01
dT air [°C]=	7.24
dT fluid [°C]=	0.86
dT1 [°C]=	8.02
dT2 [°C]=	1.64
LMTD [°C]=	4.02
Qref [kW]=	0.8457
mair [kg/s]=	0.1162

Package Temperatures (°C) 08/15/97 Freezium45%

(Based on ASHRAE Standard)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-20.8	-17.31	-13.61	-13.72	-5.777	-6.575	-21.44	-15.46	-12.8	-16.88	-6.495	-8.98
2	-19.38	-16.73	-13.52	-10.59	-5.339	-6.25	-18.95	-14.89	-12.62	-13.33	-6.137	-8.32
3	-18.91	-16.82	-13.29	-11.88	-5.354	-6.115	-18.93	-14.86	-12.48	-14.04	-6.177	-8.11
4	-19.28	-16.91	-13.23	-13.18	-5.37	-5.994	-19.62	-14.88	-12.33	-14.98	-6.118	-8.14
5	-20.24	-17.43	-13.68	-14.3	-5.773	-6.633	-20.99	-15.62	-13.01	-16.39	-6.732	-8.92
6	-20.55	-17.49	-13.82	-14.04	-5.755	-6.677	-21.17	-15.72	-13.18	-16.39	-6.742	-9.07
7	-20.46	-17.47	-13.89	-13.77	-5.74	-6.648	-20.85	-15.66	-13.23	-16.21	-6.708	-8.98
8	-20.55	-17.64	-14.09	-13.9	-5.93	-6.961	-21	-15.97	-13.61	-16.45	-7.04	-9.28
9	-19.38	-16.73	-13.52	-10.59	-5.339	-6.25	-18.95	-14.89	-12.62	-13.33	-6.137	-8.32
AV	-19.95	-17.17	-13.63	-12.89	-5.60	-6.46	-20.21	-15.33	-12.88	-15.33	-6.48	-8.68

Warmest Test Package	-5.60
Coldest Test Package	-20.21
Average Test Package	-12.88

Appendix 3

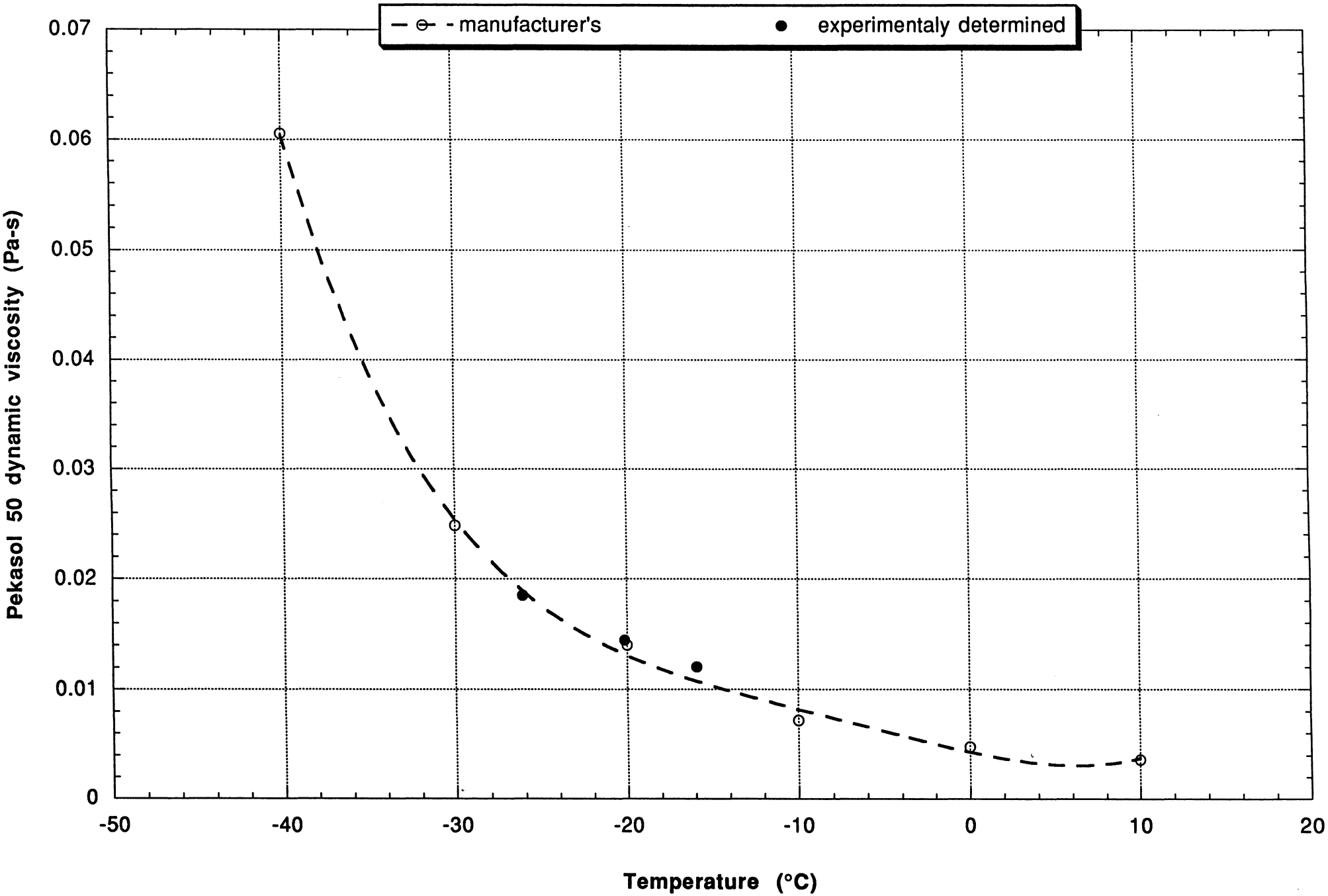
Pekasol 50 test data

Table of Contents

Test Data Summary Table of Pekasol 50								
DATE	8/21/97	9/2/97	9/5/97	9/7/97	9/12/97	9/18/97		
mdot [g/s] =	124.17	62.51	146.69	56.6	104.98	67.57		
Pressures								
Prout [kPa] =	135.19	128.74	133.82	131.28	127.74	125.41		
Power Usage								
W1 [kPa] =	308.11	501.59	744.08	664.98	284.96	243.46		
General Temp								
Tref [°C] =	26.85	27.31	26.15	26.41	25.95	26.22		
Tdb [°C] =	23.34	23.59	24.11	24.06	23.88	23.84		
Twb [°C] =	18.03	19.66	17.73	18.05	17.71	17.93		
Case Inlet								
Trin [°C] =	-27.81	-27.28	-15.26	-14.13	-22.43	-21.71		
HX Inlet								
Tri-1 [°C] =	-27.51	-26.93	-15.1	-13.96	-22.28	-21.39		
Tri-2 [°C] =	-27.68	-27.17	-15.18	-13.99	-22.4	-21.67		
Tri-3 [°C] =	-27.62	-27.15	-15.12	-13.96	-22.29	-21.62		
Tri av [°C] =	-27.6	-27.08	-15.13	-13.97	-22.23	-21.56		
Pass 1								
Tr1-1 [°C] =	-26.92	-25.51	-14.7	-12.69	-21.68	-20.32		
Tr1-2 [°C] =	-25.65	-25.71	-14.52	-12.44	-21.44	-20.1		
Tr1-3 [°C] =	-26.81	-25.54	-14.63	-12.4	-21.6	-20.26		
Tri av [°C] =	-25.79	-25.44	-14.62	-12.51	-21.58	-20.22		
Pass 2								
Tr2-1 [°C] =	-26.37	-24.27	-14.39	-11.74	-21.09	-19.42		
Tr2-2 [°C] =	-26.1	-24.13	-14.17	-11.52	-20.85	-19.26		
Tr2-3 [°C] =	-25.98	-24.06	-14.04	-11.36	-20.85	-19.14		
Tr2 av [°C] =	-26.15	-24.16	-14.2	-11.54	-20.93	-19.28		
Pass 3								
Tr3-1 [°C] =	-25.69	-23.37	-13.9	-11.04	-20.42	-18.65		
Tr3-2 [°C] =	-25.56	-23.33	-13.75	-10.91	-20.27	-18.55		
Tr3-3 [°C] =	-25.62	-23.17	-13.68	-10.61	-20.28	-18.37		
Tr3 av [°C] =	-25.63	-23.29	-13.78	-10.85	-20.33	-18.52		
HX Outlet								
Tro-1 [°C] =	-24.49	-22.22	-12.87	-10	-19.18	-17.45		
Tro-2 [°C] =	-24.52	-22.33	-12.92	-10.09	-19.3	-17.59		
Tro-3 [°C] =	-24.42	-22.2	-12.71	-10.08	-19.18	-17.51		
Tro av [°C] =	-24.48	-22.25	-12.83	-10.06	-19.22	-17.52		
Case Outlet								
Trout [°C] =	-24.59	-22.22	-13.48	-9.83	-19.5	-17.29		
Case Delivered								
Tad-1 [°C] =	-22.13	-20.89	-10.61	-8.6	-17.39	-16.14		
Tad-2 [°C] =	-21.74	-20.31	-10.06	-7.86	-15.4	-13.98		
Tad-3 [°C] =	-23.95	-22.39	-12.53	-10.31	-19.21	-17.71		
Tad-4 [°C] =	-24.31	-15.83	-9.74	-10.16	-19.18	-17.62		
Tad av [°C] =	-23.03	-19.85	-10.74	-9.23	-17.8	-16.36		

DATE	8/21/97	9/2/97	9/5/97	9/7/97	9/12/97	9/18/97		
Case Center								
Tac-1 [°C] =	21.81	22.03	23.03	23.13	22.48	22.56		
Tac-2 [°C] =	-17.69	-15.85	-7.68	-5.56	-13.44	-12.12		
Tac-3 [°C] =	-25.3	-23.79	-13.51	-11.27	-20.16	-18.78		
Case Returned								
Tar-1 [°C] =	-13.34	-12.87	-3.92	-2.32	-9.77	-8.69		
Tar-2 [°C] =	-14.28	-12.68	-5.19	-3.22	-10.92	-9.46		
Tar-3 [°C] =	-16.62	-14.62	-7.48	-5.31	-13.43	-12.05		
Tar-4 [°C] =	-10.64	-9.09	-2.95	-0.65	-8.04	-6.64		
Tar av [°C] =	-13.72	-12.31	-4.88	-2.87	-10.54	-9.21		
HX Load								
Qref [kW] =	1.2574	0.9965	0.8302	0.7739	0.9278	0.9449		
Defrost								
Tdef [°C] =	30	31	30	32	32.4	30.2		
Time [min.] =	9	11	8.8	9	7.5	10.5		
mdef [g/s] =	460	576	418	218	374	278		
Water [L] =	2.112	2.609	1.93	2.08	2.031	2.163		
Note: The dehumidifier was on when W1>300 W.								

Pekasol50 property 9/17/97



Average values of data during last 3/4's of running cycle (SI)

TYLER SECONDARY TEST (FLUID USED: Pekasol 50)

DATE:	8/21/97
MINUTES:	1080

MASS FLOW RATE	
mdot2 [g/s] =	124.17

DIFF PRESSURE HX	
DPhx [Pa] =	6999.00

POWER USAGE	
W1 [W] =	308.11

GENERAL TEMPERATURES	
Tref [°C] =	26.85
Tdb [°C] =	23.34
Twb [°C] =	18.03

DEFROST: TEMP. WATER	
Tdef [°C] =	30
Water [L] =	2.112

CASE INLET	
Trin [°C] =	-27.81

EVAPORATOR INLET	
Tri-1 [°C] =	-27.51
Tri-2 [°C] =	-27.68
Tri-3 [°C] =	-27.62
Tri av [°C] =	-27.60

EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-26.92
Tr1-2 [°C] =	-26.65
Tr1-3 [°C] =	-26.81
Tr1 av [°C] =	-26.79

EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-26.37
Tr2-2 [°C] =	-26.10
Tr2-3 [°C] =	-25.98
Tr2 av [°C] =	-26.15

EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-25.69
Tr3-2 [°C] =	-25.56
Tr3-3 [°C] =	-25.62
Tr3 av [°C] =	-25.63

EVAPORATOR OUTLET	
Tro-1 [°C] =	-24.49
Tro-2 [°C] =	-24.52
Tro-3 [°C] =	-24.42
Tro av [°C] =	-24.48

CASE OUTLET	
Trout [°C] =	-24.59

PACKAGE TEMPERATURES	
P-1 [°C] =	-19.21
P-2 [°C] =	-12.15
P-3 [°C] =	-12.83
P-4 [°C] =	-23.89
P-5 [°C] =	-19.46
P-6 [°C] =	-17.77
P-7 [°C] =	-23.49
P-8 [°C] =	-10.67
P-9 [°C] =	-11.38
P-10 [°C] =	-23.49
P-11 [°C] =	-20.99
P-12 [°C] =	-18.00
Paverage[°C]=	-17.78

CASE AIR: DELIVERED	
Tad-1 [°C] =	-22.13
Tad-2 [°C] =	-21.74
Tad-3 [°C] =	-23.95
Tad-4 [°C] =	-24.31
Tad av [°C] =	-23.03

CASE AIR: CENTER	
Tac-1 [°C] =	21.81
Tac-2 [°C] =	-17.69
Tac-3 [°C] =	-25.30

CASE AIR: RETURNED	
Tar-1 [°C] =	-13.34
Tar-2 [°C] =	-14.28
Tar-3 [°C] =	-16.62
Tar-4 [°C] =	-10.64
Tar av [°C] =	-13.72

CHILLER SYSTEM

PRESSURES	*(Absolute)*
Prin [kPa] =	
Prout [kPa] =	135.19

SAT TEMP (Prout)	
Tsat [°C] =	-38.92

2nd Fluid in System	
Tlin [°C] =	-25.73
Tlout [°C] =	-29.11
Tpumpin[C]=	-25.91
Tpumpout[C]=	-23.49

PLATE HX	
Txv1 [°C] =	23.90
Tpin1 [°C] =	
Tpout1 [°C] =	
Tsin1 [°C] =	
Tsout1 [°C] =	
SUPERHEAT	
[°C] =	

SHELL & TUBE HX	
Txv1 [°C] =	23.90
Tpin2 [°C] =	-39.58
Tpout2 [°C] =	-28.81
Tsin2 [°C] =	-25.18
Tsout2 [°C] =	-32.67
SUPERHEAT	
[°C] =	10.11

Calculations (SI)

2ND FLUID PROPERTIES	
Temp =	-27.81
Density =	1268.61
Spec Heat =	3.15
Dynamic Visco	2.18E-02

TUBES IN HX	
ID [mm]=	13.84
Area [m^2]=	1.50E-04
Vdot [m^3/s]=	3.26E-05
Vel [m/s]=	0.217
Re [-]=	174.56

TUBES IN MAIN PIPE	
ID [mm]=	19.94
Area [m^2]=	3.12E-04
Vdot [m^3/s]=	9.79E-05
Vel [m/s]=	0.313
Re [-]=	363.47

HX LOAD	
Tavg [°C]=	-21.49
Cp air =	1.00
dT air [°C]=	7.61
dT fluid [°C]=	3.22
dT1 [°C]=	6.90
dT2 [°C]=	2.51
LMTD [°C]=	4.34
Qref [kW]=	1.2574
mair [kg/s]=	0.1645

Package Temperatures (°C) 08/21/97 Pekasol50

(Based on ASHRAE Standard)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-23.95	-21.4	-18.59	-17.14	-10.53	-11.93	-24.48	-19.97	-18.32	-19.97	-12.58	-13.39
2	-21.28	-20.34	-18.03	-12.16	-8.82	-10.26	-21.22	-18.74	-17.7	-14.65	-10.65	-11.38
3	-20.99	-20.35	-17.39	-13.51	-8.9	-9.9	-20.99	-18.48	-16.99	-15.63	-10.71	-10.96
4	-21.35	-20.43	-17.36	-14.8	-9.45	-10.24	-21.45	-18.71	-16.96	-17.04	-11.21	-11.39
5	-21.76	-20.48	-17.43	-15.49	-9.84	-10.54	-21.81	-18.88	-17.06	-17.86	-11.49	-11.79
6	-22.25	-20.54	-17.53	-15.95	-10.08	-10.74	-22.17	-19.02	-17.18	-18.39	-11.68	-12.1
7	-22.59	-20.62	-17.6	-16.24	-10.24	-10.87	-22.79	-19.12	-17.31	-18.73	-11.82	-12.3
8	-22.85	-20.69	-17.64	-16.45	-10.35	-10.94	-23.29	-19.16	-17.39	-18.91	-11.86	-12.41
9	-21.12	-20.32	-17.75	-12.35	-8.71	-9.98	-21.05	-18.53	-17.41	-14.59	-10.5	-11.07
AV	-22.02	-20.57	-17.70	-14.90	-9.66	-10.60	-22.14	-18.96	-17.37	-17.31	-11.39	-11.87

Warmest Test Package	-9.66
Coldest Test Package	-22.14
Average Test Package	-16.21

Average values of data during last 3/4's of running cycle (SI)

TYLER SECONDARY TEST (FLUID USED: Pekasol 50)

DATE:	9/2/97
MINUTES:	1080

MASS FLOW RATE	
mdot2 [g/s] =	62.51

DIFF PRESSURE HX	
DPhx [Pa] =	5146.27

POWER USAGE	
W1 [W] =	501.59

GENERAL TEMPERATURES	
Tref [°C] =	27.31
Tdb [°C] =	23.59
Twb [°C] =	19.66

DEFROST: TEMP. WATER	
Tdef [°C] =	31
Water [L] =	2.609

CASE INLET	
Trin [°C] =	-27.28

EVAPORATOR INLET	
Tri-1 [°C] =	-26.93
Tri-2 [°C] =	-27.17
Tri-3 [°C] =	-27.15
Tri av [°C] =	-27.08

EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-25.51
Tr1-2 [°C] =	-25.27
Tr1-3 [°C] =	-25.54
Tr1 av [°C] =	-25.44

EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-24.27
Tr2-2 [°C] =	-24.13
Tr2-3 [°C] =	-24.06
Tr2 av [°C] =	-24.16

EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-23.37
Tr3-2 [°C] =	-23.33
Tr3-3 [°C] =	-23.17
Tr3 av [°C] =	-23.29

EVAPORATOR OUTLET	
Tro-1 [°C] =	-22.22
Tro-2 [°C] =	-22.33
Tro-3 [°C] =	-22.20
Tro av [°C] =	-22.25

CASE OUTLET	
Trout [°C] =	-22.22

PACKAGE TEMPERATURES	
P-1 [°C] =	-17.92
P-2 [°C] =	-10.57
P-3 [°C] =	-11.31
P-4 [°C] =	-21.68
P-5 [°C] =	-17.83
P-6 [°C] =	-16.06
P-7 [°C] =	-21.74
P-8 [°C] =	-10.12
P-9 [°C] =	-10.19
P-10 [°C] =	-21.74
P-11 [°C] =	-19.54
P-12 [°C] =	-16.60

CASE AIR: DELIVERED	
Tad-1 [°C] =	-20.89
Tad-2 [°C] =	-20.31
Tad-3 [°C] =	-22.39
Tad-4 [°C] =	-15.83
Tad av [°C] =	-19.85

CASE AIR: CENTER	
Tac-1 [°C] =	22.03
Tac-2 [°C] =	-15.85
Tac-3 [°C] =	-23.79

CASE AIR: RETURNED	
Tar-1 [°C] =	-12.87
Tar-2 [°C] =	-12.68
Tar-3 [°C] =	-14.62
Tar-4 [°C] =	-9.09
Tar av [°C] =	-12.31

CHILLER SYSTEM

PRESSURES	*(Absolute)*
Prin [kPa] =	
Prout [kPa] =	128.74

SAT TEMP (Prout)	
Tsat [°C] =	-39.83

2nd Fluid in System	
Tlin [°C] =	-22.77
Tlout [°C] =	-28.56
Tpumpin[C]=	-25.78
Tpumpout[C]=	-23.43

PLATE HX	
Txv1 [°C] =	23.31
Tpin1 [°C] =	
Tpout1 [°C] =	
Tsin1 [°C] =	
Tsout1 [°C] =	
SUPERHEAT	
[°C] =	

SHELL & TUBE HX	
Txv1 [°C] =	23.31
Tpin2 [°C] =	-40.45
Tpout2 [°C] =	-28.00
Tsin2 [°C] =	-21.98
Tsout2 [°C] =	-31.41
SUPERHEAT	
[°C] =	11.83

Calculations (SI)

2ND FLUID PROPERTIES	
Temp =	-27.28
Density =	1268.48
Spec Heat =	3.15
Dynamic Visco	2.12E-02

TUBES IN HX	
ID [mm]=	13.84
Area [m^2]=	1.50E-04
Vdot [m^3/s]=	1.64E-05
Vel [m/s]=	0.109
Re [-]=	90.55

TUBES IN MAIN PIPE	
ID [mm]=	19.94
Area [m^2]=	3.12E-04
Vdot [m^3/s]=	4.93E-05
Vel [m/s]=	0.158
Re [-]=	188.54

HX LOAD	
Tavg [°C]=	-19.82
Cp air =	1.00
dT air [°C]=	7.94
dT fluid [°C]=	5.06
dT1 [°C]=	6.36
dT2 [°C]=	3.49
LMTD [°C]=	4.78
Qref [kW]=	0.9965
mair [kg/s]=	0.1249

Package Temperatures (°C) 09/02/97 Pekasol50

(Based on ASHRAE Standard)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-22.21	-19.51	-16.77	-15.08	-10.05	-10.21	-21.85	-17.7	-15.95	-18.24	-10.43	-10.99
2	-21.04	-18.9	-16.44	-11.86	-8.72	-9.28	-20.86	-17.15	-15.68	-14.62	-9.44	-9.95
3	-20.28	-18.81	-16	-12.23	-8.75	-8.99	-20.46	-16.87	-15.2	-14.72	-9.43	-9.73
4	-18.85	-15.93	-13.23	-9.13	-9.15	-20.46	-16.96	-15.12	-15.43	-9.72	-10.01	-11.09
5	-20.55	-18.93	-15.98	-13.87	-9.43	-9.36	-20.66	-17.13	-15.21	-16.08	-9.93	-10.32
6	-20.86	-19.01	-16.06	-13.96	-9.64	-9.6	-20.93	-17.34	-15.38	-16.64	-10.13	-10.57
7	-21.1	-19.08	-16.11	-14.22	-9.76	-9.72	-21.14	-17.43	-15.5	-17.02	-10.2	-10.71
8	-21.31	-19.14	-16.16	-14.51	-9.83	-9.79	-21.28	-17.5	-15.6	-17.29	-10.25	-10.84
9	-21.04	-18.9	-16.44	-11.86	-8.72	-9.28	-20.86	-17.15	-15.68	-14.62	-9.44	-9.95
AV	-20.80	-18.69	-15.91	-12.97	-9.34	-10.74	-20.56	-17.04	-15.51	-15.44	-9.92	-10.46

Warmest Test Package	-9.34
Coldest Test Package	-20.80
Average Test Package	-14.78

Average values of data during last 3/4's of running cycle (SI)

TYLER SECONDARY TEST (FLUID USED: Pekasol 50)

DATE:	9/5/97
MINUTES:	1080

MASS FLOW RATE	
mdot2 [g/s] =	146.69

DIFF PRESSURE HX	
DPhx [Pa] =	6999.00

POWER USAGE	
W1 [W] =	744.08

GENERAL TEMPERATURES	
Tref [°C] =	26.15
Tdb [°C] =	24.11
Twb [°C] =	17.73

DEFROST: TEMP. WATER	
Tdef [°C] =	30
Water [L] =	1.93

CASE INLET	
Trin [°C] =	-15.26

EVAPORATOR INLET	
Tri-1 [°C] =	-15.10
Tri-2 [°C] =	-15.18
Tri-3 [°C] =	-15.12
Tri av [°C] =	-15.13

EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-14.70
Tr1-2 [°C] =	-14.52
Tr1-3 [°C] =	-14.63
Tr1 av [°C] =	-14.62

EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-14.39
Tr2-2 [°C] =	-14.17
Tr2-3 [°C] =	-14.04
Tr2 av [°C] =	-14.20

EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-13.90
Tr3-2 [°C] =	-13.75
Tr3-3 [°C] =	-13.68
Tr3 av [°C] =	-13.78

EVAPORATOR OUTLET	
Tro-1 [°C] =	-12.87
Tro-2 [°C] =	-12.92
Tro-3 [°C] =	-12.71
Tro av [°C] =	-12.83

CASE OUTLET	
Trout [°C] =	-13.48

PACKAGE TEMPERATURES	
P-1 [°C] =	-8.99
P-2 [°C] =	-4.19
P-3 [°C] =	-4.19
P-4 [°C] =	-12.63
P-5 [°C] =	-9.96
P-6 [°C] =	-8.41
P-7 [°C] =	-12.80
P-8 [°C] =	-3.83
P-9 [°C] =	-3.35
P-10 [°C] =	-12.80
P-11 [°C] =	-11.28
P-12 [°C] =	-8.83

CASE AIR: DELIVERED	
Tad-1 [°C] =	-10.61
Tad-2 [°C] =	-10.06
Tad-3 [°C] =	-12.53
Tad-4 [°C] =	-9.74
Tad av [°C] =	-10.74

CASE AIR: CENTER	
Tac-1 [°C] =	23.03
Tac-2 [°C] =	-7.68
Tac-3 [°C] =	-13.51

CASE AIR: RETURNED	
Tar-1 [°C] =	-3.92
Tar-2 [°C] =	-5.19
Tar-3 [°C] =	-7.48
Tar-4 [°C] =	-2.95
Tar av [°C] =	-4.88

CHILLER SYSTEM

PRESSURES	*(Absolute)*
Prin [kPa] =	
Prout [kPa] =	133.82

SAT TEMP (Prout)	
Tsat [°C] =	-39.11

2nd Fluid in System	
Tlin [°C] =	-13.97
Tlout [°C] =	-17.92
Tpumpin[C]=	-15.76
Tpumpout[C]=	-14.56

PLATE HX	
Txv1 [°C] =	21.58
Tpin1 [°C] =	
Tpout1 [°C] =	
Tsin1 [°C] =	
Tsout1 [°C] =	
SUPERHEAT	
[°C] =	

SHELL & TUBE HX	
Txv1 [°C] =	21.58
Tpin2 [°C] =	-39.49
Tpout2 [°C] =	-17.00
Tsin2 [°C] =	-13.63
Tsout2 [°C] =	-25.23
SUPERHEAT	
[°C] =	22.11

Calculations (SI)

2ND FLUID PROPERTIES	
Temp =	-15.26
Density =	1265.50
Spec Heat =	3.18
Dynamic Visco	1.03E-02

TUBES IN HX	
ID [mm]=	13.84
Area [m^2]=	1.50E-04
Vdot [m^3/s]=	3.86E-05
Vel [m/s]=	0.257
Re [-]=	434.70

TUBES IN MAIN PIPE	
ID [mm]=	19.94
Area [m^2]=	3.12E-04
Vdot [m^3/s]=	1.16E-04
Vel [m/s]=	0.371
Re [-]=	905.16

HX LOAD	
Tavg [°C]=	-10.60
Cp air =	1.01
dT air [°C]=	5.83
dT fluid [°C]=	1.78
dT1 [°C]=	5.79
dT2 [°C]=	1.74
LMTD [°C]=	3.37
Qref [kW]=	0.8302
mair [kg/s]=	0.1415

Package Temperatures (°C) 09/05/97 Pekasol50

(Based on ASHRAE Standard)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-12.74	-11.1	-8.74	-5.51	-3.549	-3.126	-12.39	-9.92	-8.34	-8.44	-4.078	-4.052
2	-12.96	-11.35	-9.21	-6.221	-4.23	-3.765	-12.39	-9.96	-8.5	-8.58	-4.47	-4.272
3	-13.19	-11.51	-9.06	-6.632	-4.075	-3.57	-12.93	-10.13	-8.64	-9.32	-4.397	-4.368
4	-13.1	-11.48	-9.02	-6.582	-4.036	-3.532	-12.87	-10.11	-8.61	-9.28	-4.373	-4.339
5	-13.03	-11.43	-8.99	-6.526	-3.985	-3.507	-12.77	-10.07	-8.56	-9.2	-4.312	-4.302
6	-12.94	-11.4	-8.96	-6.451	-3.95	-3.467	-12.77	-10.05	-8.53	-9.11	-4.286	-4.277
7	-12.88	-11.34	-8.92	-6.416	-3.912	-3.427	-12.64	-10.02	-8.5	-9.05	-4.256	-4.255
8	-12.82	-11.33	-8.87	-6.385	-3.865	-3.399	-12.6	-9.99	-8.46	-9	-4.228	-4.222
9	-12.74	-11.1	-8.74	-5.51	-3.549	-3.126	-12.39	-9.92	-8.34	-8.44	-4.078	-4.052
AV	-12.93	-11.34	-8.95	-6.25	-3.91	-3.44	-12.64	-10.02	-8.50	-8.94	-4.28	-4.24

Warmest Test Package	-3.44
Coldest Test Package	-12.93
Average Test Package	-7.95

Average values of data during last 3/4's of running cycle (SI)

TYLER SECONDARY TEST (FLUID USED: Pekasol 50)

DATE:	9/7/97
MINUTES:	1080

MASS FLOW RATE	
mdot2 [g/s] =	56.60

DIFF PRESSURE HX	
DPhx [Pa] =	2600.34

POWER USAGE	
W1 [W] =	664.98

GENERAL TEMPERATURES	
Tref [°C] =	26.41
Tdb [°C] =	24.06
Twb [°C] =	18.05

DEFROST: TEMP. WATER	
Tdef [°C] =	32
Water [L] =	2.08

CASE INLET	
Trin [°C] =	-14.13

EVAPORATOR INLET	
Tri-1 [°C] =	-13.96
Tri-2 [°C] =	-13.99
Tri-3 [°C] =	-13.96
Tri av [°C] =	-13.97

EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-12.69
Tr1-2 [°C] =	-12.44
Tr1-3 [°C] =	-12.40
Tr1 av [°C] =	-12.51

EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-11.74
Tr2-2 [°C] =	-11.52
Tr2-3 [°C] =	-11.36
Tr2 av [°C] =	-11.54

EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-11.04
Tr3-2 [°C] =	-10.91
Tr3-3 [°C] =	-10.61
Tr3 av [°C] =	-10.85

EVAPORATOR OUTLET	
Tro-1 [°C] =	-10.00
Tro-2 [°C] =	-10.09
Tro-3 [°C] =	-10.08
Tro av [°C] =	-10.06

CASE OUTLET	
Trout [°C] =	-9.83

PACKAGE TEMPERATURES	
P-1 [°C] =	-6.93
P-2 [°C] =	-3.04
P-3 [°C] =	-3.04
P-4 [°C] =	-10.15
P-5 [°C] =	-8.51
P-6 [°C] =	-7.04
P-7 [°C] =	-10.98
P-8 [°C] =	-2.58
P-9 [°C] =	-2.20
P-10 [°C] =	-10.98
P-11 [°C] =	-9.78
P-12 [°C] =	-7.56

CASE AIR: DELIVERED	
Tad-1 [°C] =	-8.60
Tad-2 [°C] =	-7.86
Tad-3 [°C] =	-10.31
Tad-4 [°C] =	-10.16
Tad av [°C] =	-9.23

CASE AIR: CENTER	
Tac-1 [°C] =	23.13
Tac-2 [°C] =	-5.56
Tac-3 [°C] =	-11.27

CASE AIR: RETURNED	
Tar-1 [°C] =	-2.32
Tar-2 [°C] =	-3.22
Tar-3 [°C] =	-5.31
Tar-4 [°C] =	-0.65
Tar av [°C] =	-2.87

CHILLER SYSTEM

PRESSURES	*(Absolute)*
Prin [kPa] =	
Prout [kPa] =	131.28

SAT TEMP (Prout)	
Tsat [°C] =	-39.47

2nd Fluid in System	
Tlin [°C] =	-10.16
Tlout [°C] =	-19.63
Tpumpin[C]=	-17.26
Tpumpout[C]=	-15.23

PLATE HX	
Txv1 [°C] =	21.89
Tpin1 [°C] =	
Tpout1 [°C] =	
Tsin1 [°C] =	
Tsout1 [°C] =	
SUPERHEAT	
[°C] =	

SHELL & TUBE HX	
Txv1 [°C] =	21.89
Tpin2 [°C] =	-40.06
Tpout2 [°C] =	-18.81
Tsin2 [°C] =	-9.82
Tsout2 [°C] =	-23.10
SUPERHEAT	
[°C] =	20.66

Calculations (SI)

2ND FLUID PROPERTIES	
Temp =	-14.13
Density =	1265.23
Spec Heat =	3.18
Dynamic Visco	9.57E-03

TUBES IN HX	
ID [mm]=	13.84
Area [m^2]=	1.50E-04
Vdot [m^3/s]=	1.49E-05
Vel [m/s]=	0.099
Re [-]=	181.31

TUBES IN MAIN PIPE	
ID [mm]=	19.94
Area [m^2]=	3.12E-04
Vdot [m^3/s]=	4.47E-05
Vel [m/s]=	0.143
Re [-]=	377.53

HX LOAD	
Tavg [°C]=	-8.41
Cp air =	1.01
dT air [°C]=	5.71
dT fluid [°C]=	4.30
dT1 [°C]=	4.27
dT2 [°C]=	2.86
LMTD [°C]=	3.52
Qref [kW]=	0.7739
mair [kg/s]=	0.1348

Package Temperatures (°C) 090797 Pekasol50

(Based on ASHRAE Standard)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-11.31	-10.24	-7.99	-5.112	-2.944	-2.625	-10.91	-9.11	-7.51	-7.3	-3.417	-3.42
2	-11.12	-10.05	-8	-4.73	-2.858	-2.605	-10.01	-9.01	-7.47	-6.718	-3.352	-3.369
3	-10.99	-10.12	-7.89	-5.106	-2.856	-2.569	-10.11	-8.88	-7.35	-6.858	-3.29	-3.299
4	-11.36	-10.07	-7.8	-5.18	-2.751	-2.427	-10.58	-8.86	-7.31	-7.31	-3.235	-3.273
5	-11.28	-10.04	-7.76	-5.101	-2.719	-2.361	-10.5	-8.8	-7.25	-7.23	-3.2	-3.234
6	-11.24	-9.97	-7.73	-5.046	-2.691	-2.321	-10.42	-8.75	-7.2	-7.15	-3.165	-3.186
7	-11.15	-9.93	-7.68	-4.992	-2.663	-2.273	-10.35	-8.7	-7.18	-7.08	-3.145	-3.192
8	-11.09	-9.9	-7.68	-4.957	-2.662	-2.297	-10.39	-8.69	-7.16	-7.08	-3.147	-3.152
9	-10.74	-9.57	-7.39	-4.598	-2.454	-2.044	-9.77	-8.35	-6.855	-6.686	-2.905	-2.878
AV	-11.14	-9.99	-7.77	-4.98	-2.73	-2.39	-10.34	-8.79	-7.25	-7.05	-3.21	-3.22

Warmest Test Package	-2.39
Coldest Test Package	-11.14
Average Test Package	-6.57

Average values of data during last 3/4's of running cycle (SI)

TYLER SECONDARY TEST (FLUID USED: Pekasol 50)

DATE:	9/12/97
MINUTES:	1080

MASS FLOW RATE	
mdot2 [g/s] =	104.98

DIFF PRESSURE HX	
DPhx [Pa] =	6999.00

POWER USAGE	
W1 [W] =	284.96

GENERAL TEMPERATURES	
Tref [°C] =	25.95
Tdb [°C] =	23.88
Twb [°C] =	17.71

DEFROST: TEMP. WATER	
Tdef [°C] =	32.4
Water [L] =	2.031

CASE INLET	
Trin [°C] =	-22.43

EVAPORATOR INLET	
Tri-1 [°C] =	-22.28
Tri-2 [°C] =	-22.40
Tri-3 [°C] =	-22.29
Tri av [°C] =	-22.32

EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-21.68
Tr1-2 [°C] =	-21.44
Tr1-3 [°C] =	-21.60
Tr1 av [°C] =	-21.58

EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-21.09
Tr2-2 [°C] =	-20.85
Tr2-3 [°C] =	-20.85
Tr2 av [°C] =	-20.93

EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-20.42
Tr3-2 [°C] =	-20.27
Tr3-3 [°C] =	-20.28
Tr3 av [°C] =	-20.33

EVAPORATOR OUTLET	
Tro-1 [°C] =	-19.18
Tro-2 [°C] =	-19.30
Tro-3 [°C] =	-19.18
Tro av [°C] =	-19.22

CASE OUTLET	
Trout [°C] =	-19.50

PACKAGE TEMPERATURES	
P-1 [°C] =	-14.94
P-2 [°C] =	-7.89
P-3 [°C] =	-8.98
P-4 [°C] =	-19.28
P-5 [°C] =	-15.53
P-6 [°C] =	-13.74
P-7 [°C] =	-19.11
P-8 [°C] =	-6.24
P-9 [°C] =	-6.75
P-10 [°C] =	-19.11
P-11 [°C] =	-16.85
P-12 [°C] =	-13.65

CASE AIR: DELIVERED	
Tad-1 [°C] =	-17.39
Tad-2 [°C] =	-15.40
Tad-3 [°C] =	-19.21
Tad-4 [°C] =	-19.18
Tad av [°C] =	-17.80

CASE AIR: CENTER	
Tac-1 [°C] =	22.48
Tac-2 [°C] =	-13.44
Tac-3 [°C] =	-20.16

CASE AIR: RETURNED	
Tar-1 [°C] =	-9.77
Tar-2 [°C] =	-10.92
Tar-3 [°C] =	-13.43
Tar-4 [°C] =	-8.04
Tar av [°C] =	-10.54

CHILLER SYSTEM

PRESSURES	*(Absolute)*
Prin [kPa] =	
Prout [kPa] =	127.74

SAT TEMP (Prout)	
Tsat [°C] =	-39.97

2nd Fluid in System	
Tlin [°C] =	-141.83
Tlout [°C] =	-24.57
Tpumpin[C]=	-21.84
Tpumpout[C]=	-20.24

PLATE HX	
Txv1 [°C] =	21.47
Tpin1 [°C] =	
Tpout1 [°C] =	
Tsin1 [°C] =	
Tsout1 [°C] =	
SUPERHEAT	
[°C] =	

SHELL & TUBE HX	
Txv1 [°C] =	21.47
Tpin2 [°C] =	-40.65
Tpout2 [°C] =	-24.30
Tsin2 [°C] =	-19.76
Tsout2 [°C] =	-27.90
SUPERHEAT	
[°C] =	15.67

Calculations (SI)

2ND FLUID PROPERTIES	
Temp =	-22.43
Density =	1267.25
Spec Heat =	3.16
Dynamic Visco	1.62E-02

TUBES IN HX	
ID [mm]=	13.84
Area [m^2]=	1.50E-04
Vdot [m^3/s]=	2.76E-05
Vel [m/s]=	0.184
Re [-]=	198.71

TUBES IN MAIN PIPE	
ID [mm]=	19.94
Area [m^2]=	3.12E-04
Vdot [m^3/s]=	8.28E-05
Vel [m/s]=	0.265
Re [-]=	413.77

HX LOAD	
Tavg [°C]=	-16.80
Cp air =	1.01
dT air [°C]=	6.72
dT fluid [°C]=	2.93
dT1 [°C]=	6.05
dT2 [°C]=	2.27
LMTD [°C]=	3.86
Qref [kW]=	0.9728
mair [kg/s]=	0.1441

Package Temperatures (°C) 091297 Pekasol 50

(Based on ASHRAE Standard)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-19.21	-16.75	-13.37	-12	-5.518	-6.262	-19.54	-15.41	-13.43	-14.92	-7.25	-8.74
2	-17.79	-16.24	-13.03	-10.53	-5.14	-5.829	-17.33	-14.73	-12.98	-12.83	-6.854	-8.01
3	-17.99	-16.37	-13.04	-11.38	-5.306	-5.919	-17.89	-14.9	-13	-13.68	-7.04	-8.2
4	-18.4	-16.45	-13.05	-12.04	-5.399	-5.879	-18.53	-14.91	-12.93	-14.29	-7.07	-8.26
5	-19.62	-16.91	-13.51	-12.75	-5.864	-6.446	-19.97	-15.54	-13.59	-15.57	-7.59	-8.96
6	-19.53	-16.89	-13.55	-12.53	-5.896	-6.5	-19.8	-15.54	-13.66	-15.43	-7.64	-8.95
7	-19.42	-16.86	-13.56	-12.43	-5.919	-6.505	-19.57	-15.52	-13.69	-15.29	-7.67	-8.96
8	-19.33	-16.87	-13.56	-12.36	-5.96	-6.525	-19.44	-15.51	-13.68	-15.19	-7.69	-8.93
9	-17.78	-16.2	-13.04	-10.28	-5.092	-5.749	-17.18	-14.63	-12.93	-12.59	-6.745	-7.89
AV	-18.79	-16.62	-13.30	-11.81	-5.57	-6.18	-18.81	-15.19	-13.32	-14.42	-7.28	-8.54

Warmest Test Package	-5.57
Coldest Test Package	-18.81
Average Test Package	-12.49

Average values of data during last 3/4's of running cycle (SI)

TYLER SECONDARY TEST (FLUID USED: Pekasol 50)

DATE:	9/18/97
MINUTES:	1080

MASS FLOW RATE	
mdot2 [g/s] =	67.57

DIFF PRESSURE HX	
DPhx [Pa] =	4199.84

POWER USAGE	
W1 [W] =	243.46

GENERAL TEMPERATURES	
Tref [°C] =	26.22
Tdb [°C] =	23.84
Twb [°C] =	17.93

DEFROST: TEMP. WATER	
Tdef [°C] =	30.2
Water [L] =	2.163

CASE INLET	
Trin [°C] =	-21.71

EVAPORATOR INLET	
Tri-1 [°C] =	-21.39
Tri-2 [°C] =	-21.67
Tri-3 [°C] =	-21.62
Tri av [°C] =	-21.56

EVAPORATOR: PASS 1	
Tr1-1 [°C] =	-20.32
Tr1-2 [°C] =	-20.10
Tr1-3 [°C] =	-20.26
Tr1 av [°C] =	-20.22

EVAPORATOR: PASS 2	
Tr2-1 [°C] =	-19.42
Tr2-2 [°C] =	-19.26
Tr2-3 [°C] =	-19.14
Tr2 av [°C] =	-19.28

EVAPORATOR: PASS 3	
Tr3-1 [°C] =	-18.65
Tr3-2 [°C] =	-18.55
Tr3-3 [°C] =	-18.37
Tr3 av [°C] =	-18.52

EVAPORATOR OUTLET	
Tro-1 [°C] =	-17.45
Tro-2 [°C] =	-17.59
Tro-3 [°C] =	-17.51
Tro av [°C] =	-17.52

CASE OUTLET	
Trout [°C] =	-17.29

PACKAGE TEMPERATURES	
P-1 [°C] =	-13.33
P-2 [°C] =	-6.64
P-3 [°C] =	-7.59
P-4 [°C] =	-17.62
P-5 [°C] =	-13.68
P-6 [°C] =	-11.94
P-7 [°C] =	-17.42
P-8 [°C] =	-5.96
P-9 [°C] =	-5.81
P-10 [°C] =	-17.42
P-11 [°C] =	-15.09
P-12 [°C] =	-12.14

CASE AIR: DELIVERED	
Tad-1 [°C] =	-16.14
Tad-2 [°C] =	-13.98
Tad-3 [°C] =	-17.71
Tad-4 [°C] =	-17.62
Tad av [°C] =	-16.36

CASE AIR: CENTER	
Tac-1 [°C] =	22.56
Tac-2 [°C] =	-12.12
Tac-3 [°C] =	-18.78

CASE AIR: RETURNED	
Tar-1 [°C] =	-8.69
Tar-2 [°C] =	-9.46
Tar-3 [°C] =	-12.05
Tar-4 [°C] =	-6.64
Tar av [°C] =	-9.21

CHILLER SYSTEM

PRESSURES	*(Absolute)*
Prin [kPa] =	
Prout [kPa] =	125.41

SAT TEMP (Prout)	
Tsat [°C] =	-40.30

2nd Fluid in System	
Tlin [°C] =	-77.82
Tlout [°C] =	-24.16
Tpumpin[C]=	-21.63
Tpumpout[C]=	-19.61

PLATE HX	
Txv1 [°C] =	22.03
Tpin1 [°C] =	
Tpout1 [°C] =	
Tsin1 [°C] =	
Tsout1 [°C] =	
SUPERHEAT	
[°C] =	

SHELL & TUBE HX	
Txv1 [°C] =	22.03
Tpin2 [°C] =	-41.03
Tpout2 [°C] =	-23.84
Tsin2 [°C] =	-17.30
Tsout2 [°C] =	-27.07
SUPERHEAT	
[°C] =	16.46

Calculations (SI)

2ND FLUID PROPERTIES	
Temp =	-21.71
Density =	1267.07
Spec Heat =	3.16
Dynamic Visco	1.56E-02

TUBES IN HX	
ID [mm]=	13.84
Area [m^2]=	1.50E-04
Vdot [m^3/s]=	1.78E-05
Vel [m/s]=	0.118
Re [-]=	133.21

TUBES IN MAIN PIPE	
ID [mm]=	19.94
Area [m^2]=	3.12E-04
Vdot [m^3/s]=	5.33E-05
Vel [m/s]=	0.171
Re [-]=	277.37

HX LOAD	
Tavg [°C]=	-15.45
Cp air =	1.01
dT air [°C]=	6.67
dT fluid [°C]=	4.42
dT1 [°C]=	5.18
dT2 [°C]=	2.93
LMTD [°C]=	3.95
Qref [kW]=	0.9449
mair [kg/s]=	0.1410

Package Temperatures (°C) 09/18/97 Pekasol 50

(Based on ASHRAE Standard)

	P-10	P-11	P-12	P-7	P-8	P-9	P-4	P-5	P-6	P-1	P-2	P-3
1	-16.99	-14.79	-11.94	-9.93	-5.811	-5.702	-17.19	-13.43	-11.73	-12.73	-6.476	-7.28
2	-16.78	-14.52	-11.92	-8.53	-5.468	-5.495	-16.31	-13.32	-11.65	-11.57	-6.239	-7.04
3	-15.84	-14.33	-11.65	-8.5	-5.304	-5.299	-15.04	-12.85	-11.36	-10.82	-6.011	-6.632
4	-15.84	-14.42	-11.57	-9.22	-5.357	-5.24	-15.39	-12.87	-11.24	-11.35	-6.049	-6.637
5	-16.17	-14.54	-11.58	-9.88	-5.486	-5.254	-16.04	-12.98	-11.26	-12	-6.165	-6.806
6	-17	-14.81	-11.8	-10.57	-5.765	-5.505	-17.24	-13.33	-11.54	-12.96	-6.428	-7.21
7	-17.2	-14.88	-11.89	-10.62	-5.847	-5.61	-17.46	-13.43	-11.66	-13.12	-6.509	-7.34
8	-17.22	-14.85	-11.88	-10.57	-5.817	-5.561	-17.39	-13.39	-11.64	-13.1	-6.447	-7.3
9	-15.75	-14.32	-11.59	-8.65	-5.261	-5.215	-15.02	-12.78	-11.27	-10.87	-5.963	-6.555
AV	-16.53	-14.61	-11.76	-9.61	-5.57	-5.43	-16.34	-13.15	-11.48	-12.06	-6.25	-6.98

Warmest Test Package	-5.43
Coldest Test Package	-16.53
Average Test Package	-10.81

Appendix 4

Data acquisition, instrumentation and calibration

Table of Contents

DATA ACQUISITION SYSTEM

This appendix contains diagrams and tables to show how the instrumentation was set-up to the data acquisition system. The instruments are connected to three Campbell AM416 Relay Multiplexers, which in turn are connected to and controlled by a Campbell 21X datalogger (see figure A4-1). The datalogger is connected via RS232 to a PC, where the data can 1) be viewed on various graphs in real time and 2) is finally stored (as ASCII comma separated text).

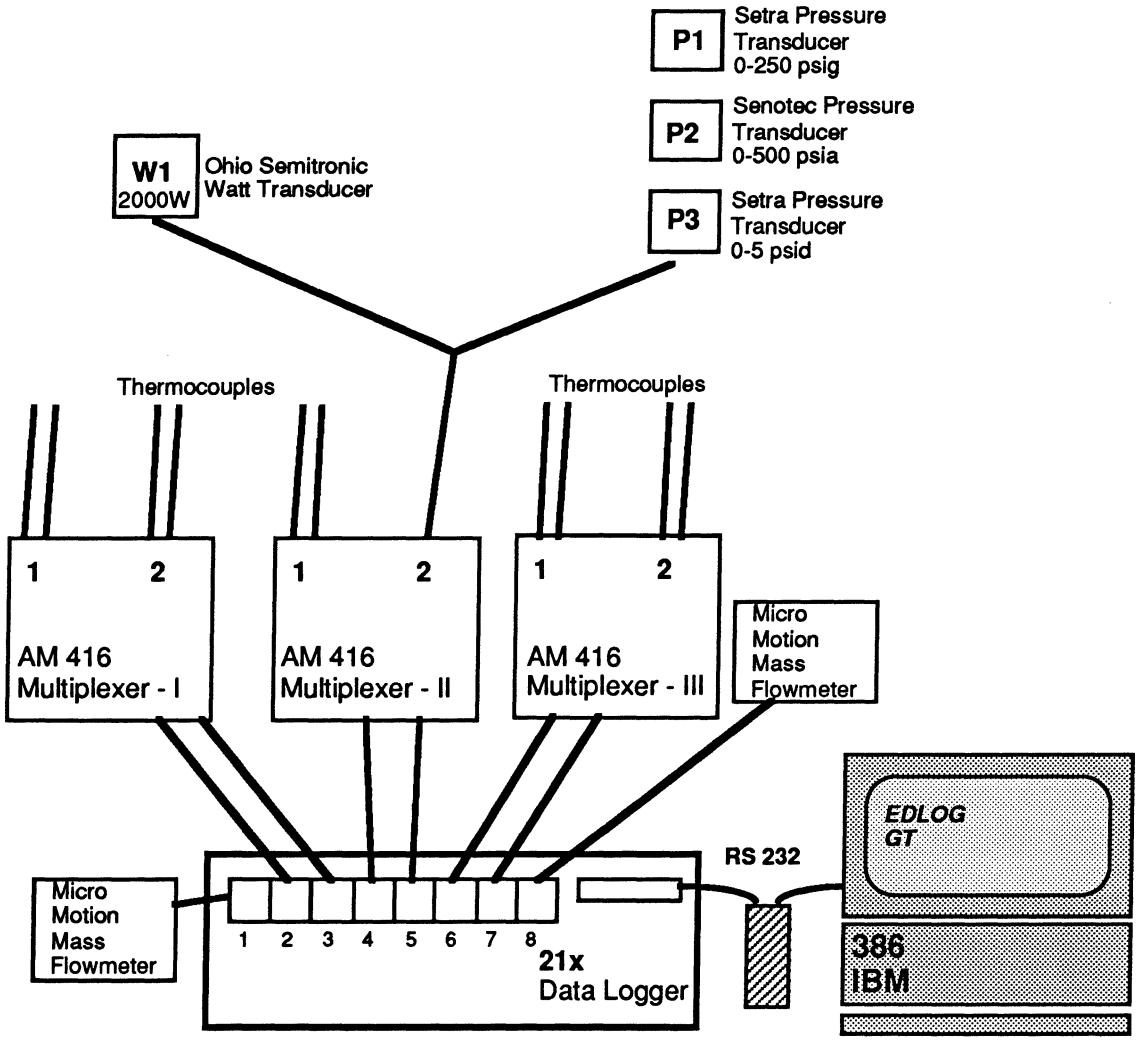


Figure A4-1. Data Acquisition Set-Up

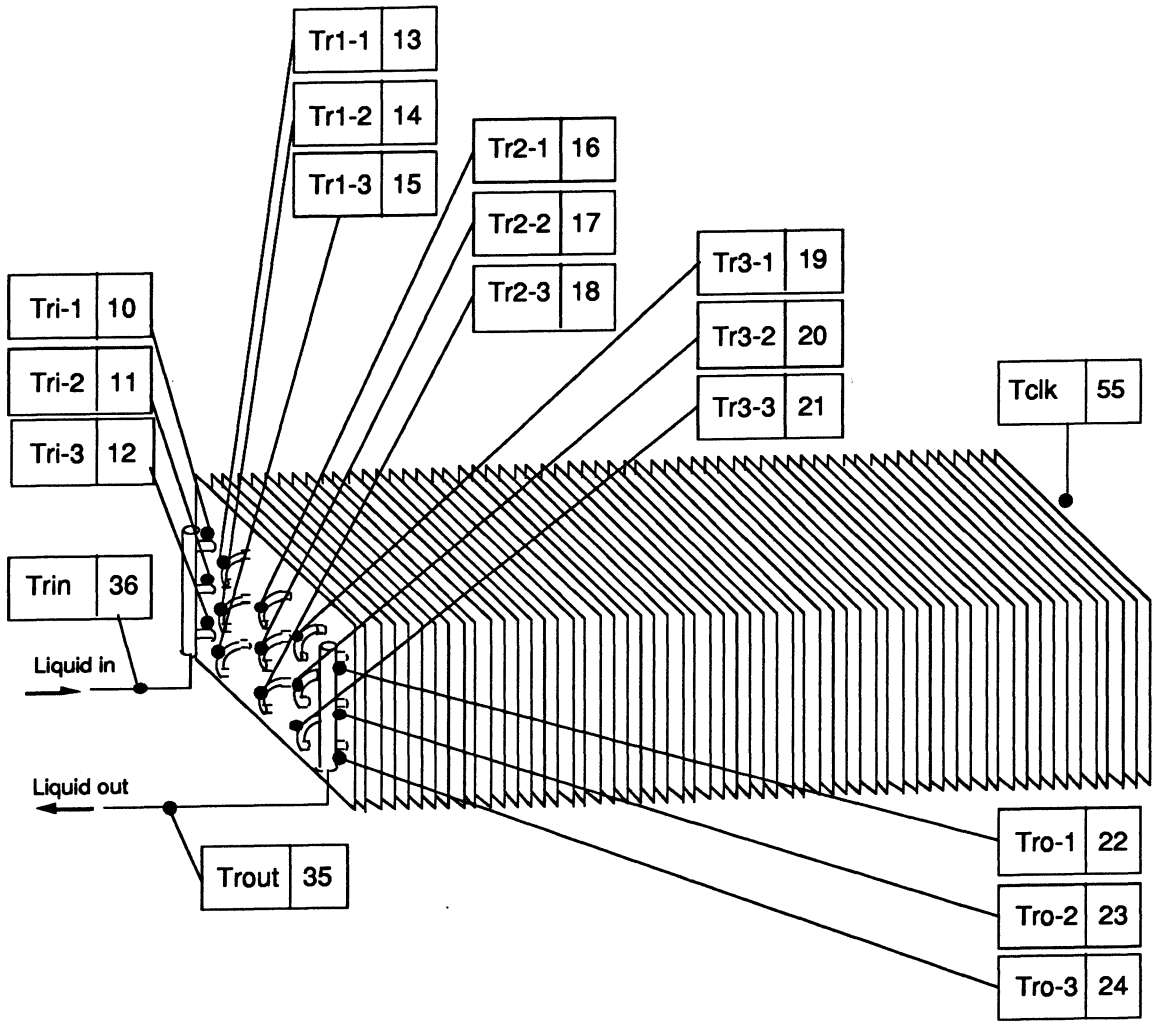


Figure A4-2. Thermocouple locations at display case heat exchanger

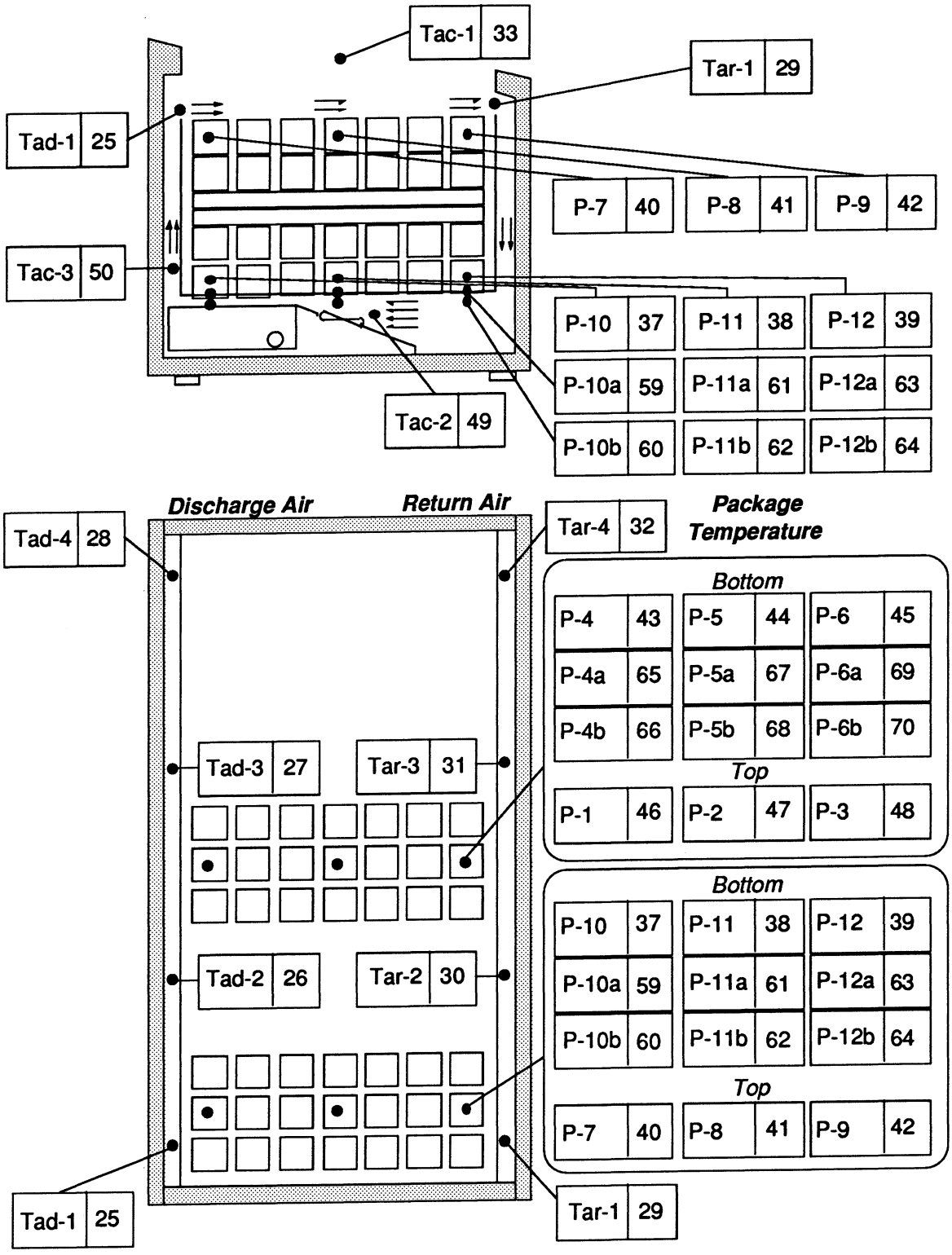


Figure A4-3. Position of Thermocouples on Display Case

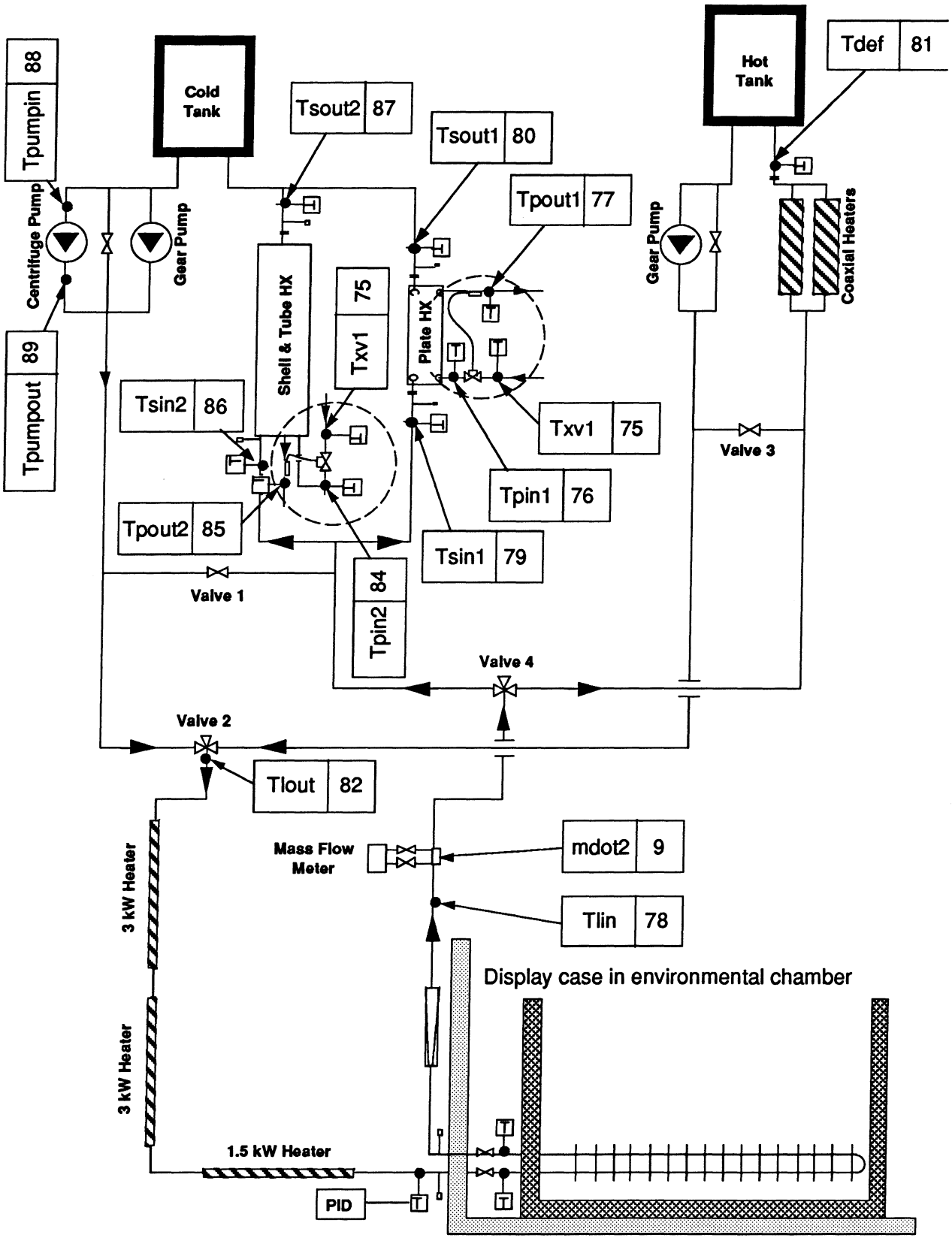


Figure A4-4. Secondary Loop Schematic

The six tables below describe where the instrument are connected on the multiplexers, which are then connected to the datalogger.

Channel	*Instrument Connected*	*Description*	*Prog Output*	*Screen #*
1	4-20mA Micromotion	mass flow rate primary loop (mdot1) m[gr/s] = 0.0055U[mV] - 5.0006	2	
2	multiplexer AM 416-I	thermocouples		
3	multiplexer AM 416-II	thermocouples		
4	multiplexer AM 416-I	thermocouples		
5	multiplexer AM 416-II			
6	multiplexer AM 416-III	thermocouples		
7	multiplexer AM 416-III	thermocouples		
8	thermocouple	mass flow rate secondary loop (mdot2) m[gr/s] = 0.1597U[mV] - 151.20	7	

Table A4-1. Data Logger 21x (Campbell Scientific) connections

location#	*Manf*	*Group*	*description*	*prog. output*	*screen #*
1	(1-1)	1	Coil inlet top pass (Tri-1)	10	
2	(1-2)	2	Coil inlet mid pass (Tri-2)	11	
3	(1-3)	3	Coil inlet bottom pass (Tri-3)	12	
4	(1-4)	4	Coil bend top left (Tr1-1)	13	
5	(1-5)	5	Coil bend mid left (Tr1-2)	14	
6	(1-6)	6	Coil bend bottom left (Tr1-3)	15	
7	(1-7)	7	Coil bend top mid (Tr2-1)	16	
8	(1-8)	8	Coil bend mid mid (Tr2-2)	17	
9	(1-9)	9	Coil bend mid bottom (Tr2-3)	18	
10	(1-10)	10	Coil bend right top (Tr3-1)	19	
11	(1-11)	11	Coil bend right mid (Tr3-2)	20	
12	(1-12)	12	Coil bend right bottom (Tr3-3)	21	
13	(2-1)	13	Coil exit top pass (Tro-1)	22	
14	(2-2)	14	Coil exit mid pass (Tro-2)	23	
15	(2-3)	15	Coil exit bottom pass (Tro-3)	24	
16	(2-4)	16	Discharge air left (Tad-1)	25	

Table A4-2. AM416 Multiplexer No. 1 (Campbell Scientific) First input terminal

AM416 Multiplexer No. 1 (Campbell Scientific)*Second input terminal*

location#	*manf*	*group*	*description*	*prog. output*	*screen #*
1	(2-5)	17	Discharge air inner left (Tad-2)	26	
2	(2-6)	18	Discharge air inner right (Tad-3)	27	
3	(2-7)	19	Discharge air right (Tad-4)	28	
4	(2-8)	20	Return air left (Tar-1)	29	
5	(2-9)	21	Return air inner left (Tar-2)	30	
6	(2-10)	22	Return air inner right (Tar-3)	31	
7	(2-11)	23	Return air right (Tar-4)	32	
8	(2-12)	24	Return above case (Tac-1)	33	
9	(3-1)	25	*(NULL)*	34	
10	(3-2)	26	Suction temp (out of case) (Trout)	35	
11	(3-3)	27	Liquid inlet case temp (Trin)	36	
12	(3-4)	28	Pack Temp: left bottom back (P-10)	37	
13	(3-5)	29	Pack Temp: left bottom mid (P-11)	38	
14	(3-6)	30	Pack temp: left bottom front (P-12)	39	
15	(3-7)	31	Pack temp: left top back (P-7)	40	
16	(3-8)	32	Pack temp: left top mid (P-8)	41	

Table A4-3. AM416 Multiplexer No. 1 (Campbell Scientific) Second input terminal

location#	*manf*	*group*	*description*	*prog. output*	*screen #*
1	(3-9)	33	Pack temp: left top front (P-9)	42	
2	(3-10)	34	Pack temp: center bottom back (P-4)	43	
3	(3-11)	35	Pack temp: center bottom mid (P-5)	44	
4	(3-12)	36	Pack temp: center bottom front (P-6)	45	
5	(4-1)	37	Pack temp: center top back (P-1)	46	
6	(4-2)	38	Pack temp: center top mid (P-2)	47	
7	(4-3)	39	Pack temp: center top front (P-3)	48	
8	(4-4)	40	Air entering the coil (Tac-2)	49	
9	(4-5)	41	Air leaving the coil (Tac-3)	50	
10	(4-6)	42	*(NULL)*	51	
11	(4-7)	43	*(NULL)*	52	
12	(4-8)	44	*(NULL)*	53	
13	(4-9)	45	*(NULL)*	54	
14		46	*(NULL)*	55	
15			Dry bulb (Tdb)	56	
16			Wet bulb (Twb)	57	

Table A4-4. AM416 Multiplexer No. 2 (Campbell Scientific) First input terminal

location#	*manf*	*group*	*description*	*prog. output*	*screen #*
1			0-5V Ohio Semitronic 2000W 115V energy usage (W1) W[Watts]= 0.4U[mV]	3	
2			*(NULL)*	4	
3			0-5V Senotec 0-500 psia pressure into chiller (Ppin) p[kPa] = 0.68811[mV]	5	
4			0.1-5.1V Setra 0-250 psig pressure out of chiller (Ppout) p[kPa]= 0.33916[mV] - 382.5	6	
5			0-5 V Setra 0-5 psid diff pressure across HX (Dphx) p[Pa] = 10.504[mV] - 11063.0	7	

Table A4-5. AM416 Multiplexer No. 2 (Campbell Scientific) Second input terminal

location#	*manf*	*group*	*description*	*prog. output*	*screen #*
1		47	Pack Temp: left bottom back (P-10a)	59	
2		48	Pack Temp: left bottom back (P-10b)	60	
3		49	Pack Temp: left bottom mid (P-11a)	61	
4		50	Pack Temp: left bottom mid (P-11b)	62	
5		51	Pack temp: left bottom front (P-12a)	63	
6		52	Pack temp: left bottom front (P-12b)	64	
7		53	Pack temp: center bottom back (P-4a)	65	
8		54	Pack temp: center bottom back (P-4b)	66	
9		55	Pack temp: center bottom mid (P-5a)	67	
10		56	Pack temp: center bottom mid (P-5b)	68	
11		57	Pack temp: center bottom front (P-6a)	69	
12		58	Pack temp: center bottom front (P-6b)	70	
13		59	Click-son temperature (Tclk)	71	
14		60	*(NULL)*	72	
15		61	*(NULL)*	73	
16		62	*(NULL)*	74	

Table A4-6. AM416 Multiplexer No. 3 (Campbell Scientific) First input terminal

location#	*manf*	*group*	*description*	*prog. output*	*screen #*
1			Prim.ref entering TXV (Txv1)	75	
2			Prim.ref entering plate HX (Tpin1)	76	
3			Prim.ref leaving plate HX (Tpout1)	77	
4			Sec.ref entering loop (Tlin)	78	
5			Sec.ref entering plate HX (Tsin1)	79	
6			Sec.ref leaving plate HX (Tsout1)	80	
7			Sec.ref in defrost loop (Tdef)	81	
8			Sec.ref out of loop (Tlout)	82	
9			*(NULL)*	83	
10			Prim. ref entering shell & tube (Tpin2)	84	
11			Prim. ref entering shell & tube (Tpout2)	85	
12			Sec. ref entering shell & tube (Tsin2)	86	
13			Sec. ref leaving shell & tube (Tsout2)	87	
14			Sec. ref entering pump (Tpumpin)	88	
15			Sec. ref leaving pump (Tpumpout)	89	
16			*(NULL)*	90	

Table A4-7. AM416 Multiplexer No. 3 (Campbell Scientific) Second input terminal

INSTRUMENTATION

Listing:

The test facility at the Commercial Refrigeration Laboratory was equipped with instruments for:

Temperature:

Temperature measurements have been done using thermocouples and thermocouple probes, type T copper - constantane

Probes: Omega TT-T-24-SLE
Wire: Special Limits of Error wire
Accuracy: ANSI Limits of error
Error: ± 0.1 °C (0.1%) - after calibration
Note: (See calibration section for details)

Temperature conversion done in the data logger using RTD as the reference junction.

Pressure:

Pressure transducers used are:

Pressure out of chiller:

Setra
Model: C206
Serial #: 349494
Pressure Range: 0 - 250 psig
Output Range: 0.1 - 5.1 V
Error: ±1.48 kPa
Note: (See calibration section for details)

Pressure into chiller:

Senotec
Model: TJE 3883-06TJA
Serial #: 493829
Pressure Range: 0 - 500 psia
Output Range: 0 - 5 V
Error: ± 0.1% F.S.
Note: (Since transducer is new, calibration curve was obtained from manufacturer)

Diff Pressure across heat exchanger:

Setra
Model: C230
Serial #: 676584
Pressure Range: 0 - 5 PSID
Output Range: 4-20 mA
Error: ± 0.087 kPa Diff (0.013 PSID)
Note: (See calibration section for details)

Refrigerant Mass Flow:

Mass flow rate primary loop

Micro Motion
Sensor
Model: S006S100
Serial #: 132174
Transmitter
Model: RFT9712
Serial #: 16239

Calibrated and adjusted for 20 g/s at 20 mA
Error: 0.2% of reading

Mass flow rate secondary loop
Micro Motion
Sensor
Model: S006S100
Serial #: 132174
Transmitter
Model: RFT9712
Serial #: 16239
Calibrated and adjusted for 20 g/s at 20 mA
Error: 0.2% of reading

Power:
Watt transducer
Ohio Semitronics
120 V Power
Model: GW5-011X5
Serial #: 6022346
2000W, 0 - 300V input, 0 - 5 V DC output

Data acquisition system::
Campbell Scientific 21x
Model : 21x
Serial #: 4261
0 - 5 V DC output
Error: 0.1% F.S.
Mutliplexer (3 units):
Model: AM416
Three units makes total of 98 channels.

CALIBRATION

Thermocouple Calibration Procedure:

The thermocouples were calibrated simultaneously using a vacuum insulated container (see figure A4-5) initially, at the beginning of the test with secondary fluids. Two temperature regimes were investigated: 0^{o} C and 23^{o} C. The water temperature was allowed to stabilize for approximately three hours before any test was conducted. As shown in the figure below, the thermocouples were bound together such that each thermocouple would measure the temperature in the same area of the container. Data was then acquired through the datalogger and PC for ten minutes with an interval of ten seconds. The temperature was also measured using a NIST thermometer once at the beginning of the test and once at the end. The data acquired through the PC was averaged. Results are shown in table A4-8 and A4-9.

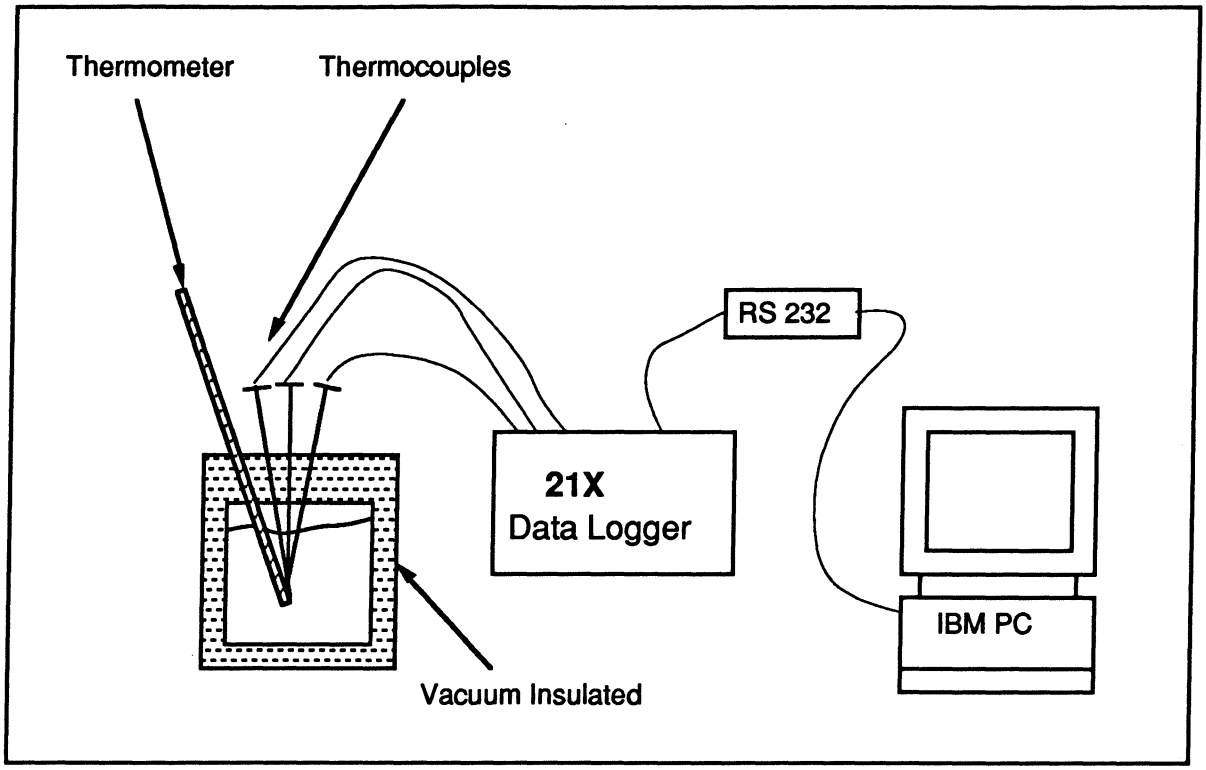


Figure A4-5. Thermocouple Calibration Set-up

	Actual (°C)			Actual (°C)	
	0.11	22.0		0.11	22.0
Tri-1	0.24	21.84	P-11	0.23	21.79
Tri-2	0.19	21.81	P-12	0.23	21.83
Tri-3	0.24	21.85	P-7	0.24	21.82
Tr1-1	0.23	21.84	P-8	0.27	21.83
Tr1-2	0.28	21.86	P-9	0.28	21.84
Tr1-3	0.29	21.87	P-4	0.28	21.85
Tr2-1	0.27	21.87	P-5	0.30	21.88
Tr2-2	0.24	21.85	P-6	0.32	21.89
Tr2-3	0.26	21.84	P-1	-0.38	21.25
Tr3-1	0.28	21.86	P-2	0.08	21.66
Tr3-2	0.26	21.88	P-3	0.26	21.86
Tr3-3	0.27	21.86	Tac-2	0.28	21.89
Tro-1	0.24	21.84	Tclk	0.26	21.91
Tro-2	0.23	21.82	P-10a	0.13	21.74
Tro-3	0.26	21.84	P-10b	0.11	21.75
Tad-1	0.22	21.83	P-11a	0.13	21.78
Tad-2	0.22	21.82	P-11b	0.13	21.77
Tad-3	0.22	21.80	P-12a	0.16	21.80
Tad-4	0.22	21.83	P-12b	0.16	21.80
Tar-1	0.24	21.84	P-4a	0.17	21.81
Tar-2	0.23	21.86	P-4b	0.19	21.82
Tar-3	0.24	21.87	P-5a	0.22	21.81
Tar-4	0.25	21.86	P-5b	0.22	21.81
Tac-1	0.26	21.86	P-6a	0.22	21.84
P-10	0.27	21.85	P-6b	0.21	21.82

Table A4-8. First Set of Results from Calibration

	Actual (°C)			Actual (°C)	
	0.38	21.50		0.11	21.94
Tpin	-0.03	21.25	Trin	0.07	21.81
Tpic	-0.01	21.25	Trout	0.12	21.82
Tpout	-0.03	21.14	Tac-3	0.29	21.82
Tlin	-0.02	21.25			
Tsin	-0.03	21.27			
Tsout	-0.02	21.28			
Tdef	0.00	21.27			
Tlout	0.02	21.27			

Table A4-9. Second Set of Results from Calibration

Pressure Transducer Calibration Procedure:

The pressure transducers were calibrated simultaneously using a pressure regulator calibration unit (see figure 4). The output voltage of each pressure transducer was measured with a multimeter at these various pressures: 0, 25, 50, 75, 100, 125, 150, 175, 200, 225, 250 psig. The pressure differential was calibrated using a U-tube manometer at various pressures.

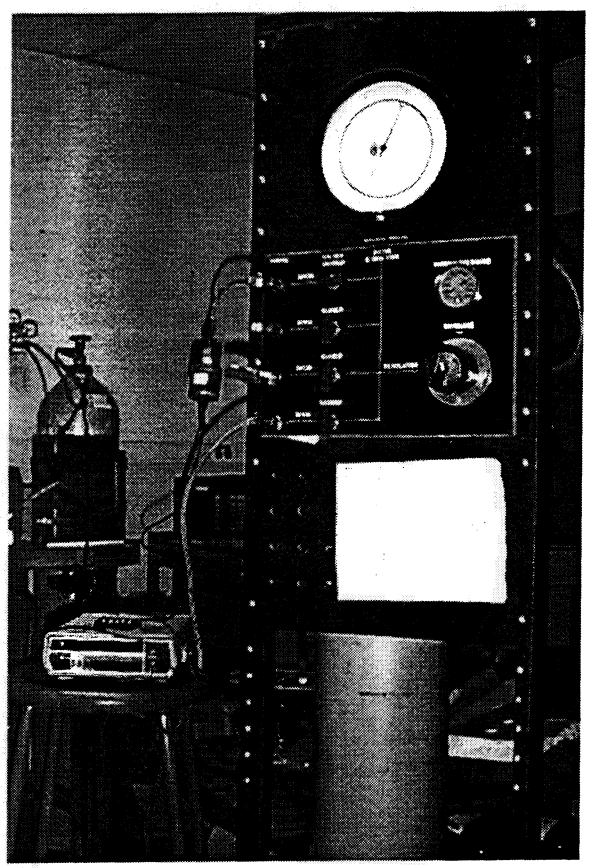


Figure A4-6. Pressure Calibration Set-Up

The pressure was plotted versus the output voltage from each transducer. Regression analysis provided best fit. The following figure (figure A4-7 and A4-8) shows the data points from the calibration of a Setra Pressure Transducer that was used the testing. Note that the Senotec pressure transducer is brand new, so the calibration curve from the manufacturer is used.

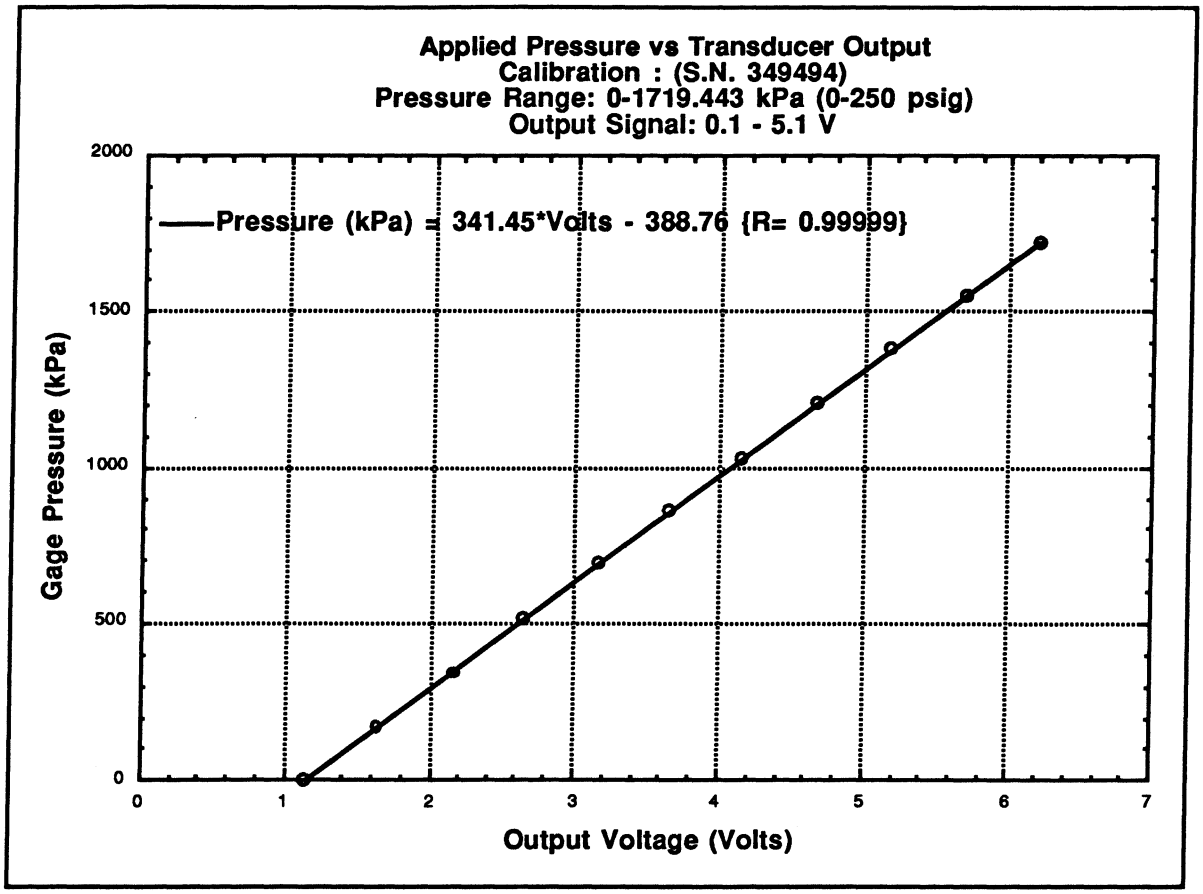


Figure A4-7. Calibration Curve for Transducer used in Testing

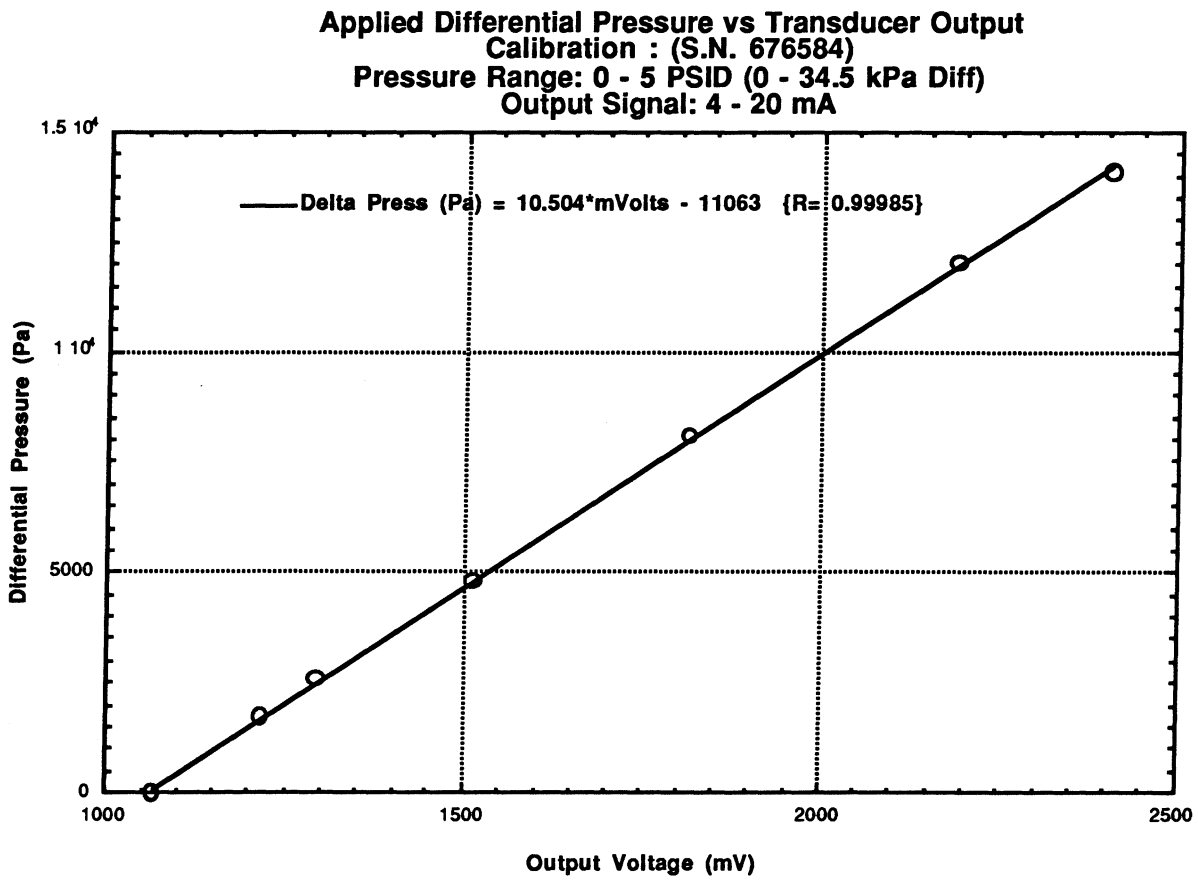


Figure A4-8. Calibration Curve for Pressure Differential used in Testing

Once the calibration curve was plotted, the uncertainty for the pressure transducer was calculated so that percent uncertainty of the Total Load for "Refrigerating Time" and the Reduced Average Load for the Overall Time Period could be determined. The uncertainty of the pressure transducer reading are calculated based on ASHRAE Standard 2-1986 as:

$$\text{uncertainty} = \frac{t\sigma'}{\sqrt{n}}$$

$$\sigma' = \frac{1}{n-1}\sum_{i=1}^{n}\sqrt{(p_i - \bar{p})^2}$$

where:

n	number of points used in calibrating transducers
t	value determined from t-distribution chart for (n-1) degrees of freedom (F) and 95% probability (P)
σ'	standard deviation
pi	pressure data point
$\bar{p}$	pressure obtained from calibration curve

The table below shows what the values for the uncertainty.

Press (gage)	Press (kPa)	Output Voltage	Press Cal Curv		(Press-Curve)^2
0	0	1.143	1.517		2.302
25	172.369	1.637	170.194		4.732
50	344.738	2.156	347.406		7.119
75	517.107	2.647	515.058		4.198
100	689.476	3.166	692.271		7.810
125	861.845	3.66	860.947		0.806
150	1034.214	4.16	1031.672		6.462
175	1206.583	4.67	1205.812		0.595
200	1378.952	5.17	1376.537		5.835
225	1551.321	5.69	1554.091		7.670
250	1723.69	6.19	1724.816		1.267
	n	*11*	σ'	*2.209 kPa*	
	t	*2.228*	*Error*	*±1.484 kPa*	

Table A4-10. Uncertainty Data of Setra Transducer
(Model: C206 / Serial #: 349494)
(Pressure Range: 0-250 psig / Output Range: 0.1 - 5.1 V)

Output Voltage (mVolts)	Press Diff (kPa)	Press Cal Curv		(Press-Curve)^2
1065	0	0.124		0.015
1218	1.743	1.731		0.000
1293	2.6145	2.519		0.009
1512	4.7932	4.819		0.001
1815	8.0925	8.002		0.008
2190	12.014	11.941		0.005
2404	14.069	14.189		0.014
			n	*7*
			t	*2.447*
			σ'	*0.094 kPa*
			Error	*±0.087 kPa*

Table A4-11. Uncertainty Data of Setra Transducer
(Model: C230 / Serial #: 676584)
(Pressure Range: 0-5 psid / Output Range: 4 - 20 mA)

Appendix 5

Data Reduction

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TEST PROCEDURE AND ACCEPTANCE CRITERIA

Error! No table of contents entries found. The refrigerated case is operated in the prescribed conditions as stated by the ASHRAE Standard. This conditions are:

Ambient Conditions:

- Test-room dry-bulb temperature shall be 75 F ± 3 F (23.9 C ± 1.7C)
- Test-room wet-bulb temperature shall be 64 F ± 3 F (17.8 C ± 1.7 C)
- Test-room air currents shall not exceed 50 fpm (0.25 m/s)
- Test-room lighting shall be fluorescent with an illumination of not less than 75 footcandles (800 lux)
- Power supply shall be maintained at the rated voltage, ± 2 percent, and rated frequency, ± 1 percent

Instruments Accuracy:

- All temperature measurements shall be within ± 0.9 F ± (0.5 C)
- All pressure instruments shall be within 0.25 psi (1.5 kPa) for refrigerator vapor pressure and 5 psi (34 kPa) for liquid refrigerator inlet pressure
- Time measurements shall be made with an accuracy of ± 0.5 percent

The display space is filled with test packages and dummy products as prescribed by the Standard and shown in Figure 8. After repeatable conditions occur, the recorded data for a 24 hour period is treated as one test level (defined by Standard). Repeatability of test conditions are determined by ± 0.2 °C difference in package temperatures at the beginning and end of the 24 hour period. Package temperatures generally take longer to reach steady state compared to other parameters.

In conformity with the Standard several measurements are taken One set value for the inlet case temperature will determine a test level. The data for each required test level are plotted and performance curves are developed over the desired range specified by the Standard.

Calculation of Data:

Overall Performance:

- Integrated Average Temperature (IAT)

$$IAT = \frac{\sum_{n=1}^{12}\sum_{i=1}^{8}(T_{n,i}^{packages}) + \sum_{n=1}^{12} T_{n,9}}{108}$$

n number of test packages
i number of time intervals
$T_{n,9}$ temperatures of given test package at the moment when the warmest average test package has reached it's peak temperature

- Coldest Test Package Average (CTPA)

$$CTPA = \min(n)\left\{\frac{\sum_{i=1}^{8}\left(T_{n,i}^{packages}\right) + T_{n,9}}{9}\right\}$$

- Warmest Test Package Average (WTPA)

$$WTPA = \max(n)\left\{\frac{\sum_{i=1}^{8}\left(T_{n,i}^{packages}\right) + T_{n,9}}{9}\right\}$$

- Average Refrigerant Load for "Evaporator" (Baseline) (Q_{evap})

$$Q_{evap} = \dot{m}_{avg,prim}\left[h_v(P_v,T_v) - h_l(P_l,T_l)\right]$$

h_V enthaply (kJ/kg) of leaving refrigerant vapor at P_V and T_V
h_l enthaply (kJ/kg) of entering refrigerant liquid at P_l and T_l
(Below values are average of bracketed parameters during last 3/4ths of each running cycle in 24 hour period)
$\dot{m}_{avg,prim}$ refrigerant mass flow rate of primary loop(kg/s)
P_V suction pressure (kPa) of refrigerant leaving evaporator **(Prout)**
T_V suction temperature (°C) of refrigerant leaving evaporator **(Tro-avg)**
P_l pressure (kPa) of refrigerant entering TXV to evaporator **(Prin)**
T_l temperature (°C) of refrigerant entering TXV to evaporator **(Trhx-2)**

- Average Refrigerant Load for "Refrigerating Time" (Q_{rt})

$$Q_{rt} = \dot{m}_{avg,sec}\left[\int_{T_{in}}^{T_{out}} c_{p,sr}(T)dT - \frac{\Delta P_{xchr}}{\rho_{xchr}}\right]$$

(Below values are average of bracketed parameters during last 3/4ths of each running cycle in 24 hour period)

$\dot{m}_{avg,sec}$ refrigerant mass flow rate of secondary loop(kg/s)

$c_{p,sr}$ specific heat (kJ/kg K) of fluid through heat exchanger

T_{in} temperature (°C) of secondary fluid into display case **(Trin)**

T_{out} temperature (°C) of secondary fluid out of display case **(Trout)**

ΔP_{xchr} pressure drop (kPa) across heat exchanger **(Dphx)**

ρ_{xchr} density (kg/m^3) of fluid across heat exchanger

- Average Refrigerant Load for "Evaporator" (Baseline) (Q_{evap})

$$Q_{evap} = \dot{m}_{avg,prim}\left[h_v(P_v,T_v) - h_l(P_l,T_l)\right]$$

h_V enthaply (kJ/kg) of leaving refrigerant vapor at P_V and T_V

h_l enthaply (kJ/kg) of entering refrigerant liquid at P_l and T_l

(Below values are average of bracketed parameters during last 3/4ths of each running cycle in 24 hour period)

$\dot{m}_{avg,prim}$ refrigerant mass flow rate of primary loop(kg/s)

P_V suction pressure (kPa) of refrigerant leaving evaporator **(Prout)**

T_V suction temperature (°C) of refrigerant leaving evaporator **(Tro-avg)**

P_l pressure (kPa) of refrigerant entering TXV to evaporator **(Prin)**

T_l temperature (°C) of refrigerant entering TXV to evaporator **(Trhx-2)**

Shell and Tube Heat Exchanger

- Average Refrigerant Load for Shell & Tube Heat Exchanger (Secondary) (Q_{shell})

$$Q_{evap} = \dot{m}_{avg,prim}\left[h_v(P_v,T_v) - h_l(P_l,T_l)\right]$$

h_V enthaply (kJ/kg) of leaving refrigerant vapor at P_V and T_V

h_l enthaply (kJ/kg) of entering refrigerant liquid at P_l and T_l

(Below values are average of bracketed parameters during last 3/4ths of each running cycle in 24 hour period)

$\dot{m}_{avg,prim}$ refrigerant mass flow rate of primary loop(kg/s)

P_V suction pressure (kPa) of refrigerant leaving chiller **(Ppout)**

T_V suction temperature (°C) of refrigerant leaving chiller **(Tpout)**

P_l pressure (kPa) of refrigerant entering TXV to chiller **(Ppin)**

T_l temperature (°C) of refrigerant entering TXV to chiller **(Txv)**

UA Values

- Average UA value for Evaporator (of Heat Exchanger)

$$Q = UA * LMTD$$

$$LMTD = \frac{(Tac2 - Trout) - (Tac3 - Trin)}{\ln\left(\frac{(Tac2 - Trout)}{(Tac3 - Trin)}\right)}$$

Q	Load of Evaporator (Q_{evap}) or Heat Exchanger (Q_{rt}) (see above for calculations)
LMTD	Log Mean Temperature Difference for CounterFlow Heat Exchanger (Note for Baseline Test Superheat is neglected - Trout = Trin)
Tac2	Inlet Air Temperature
Tac3	Outlet Air Temperature
Trin	Inlet Refrigerant Temperature
Trout	Outlet Refrigerant Temperature

Presentation of Data:

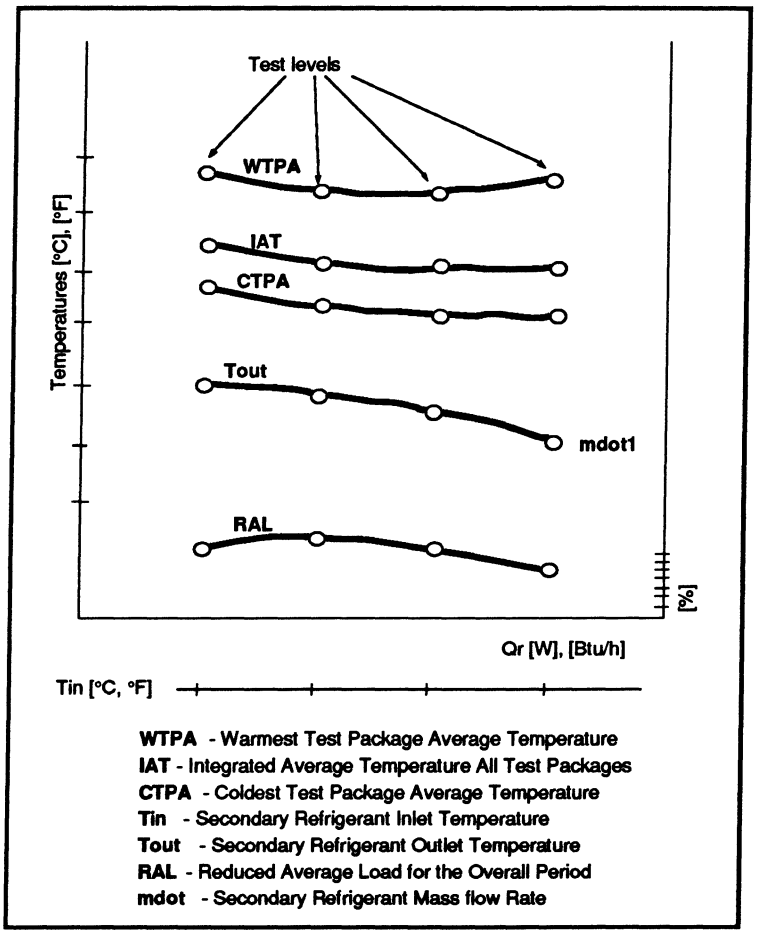

Figure A5-1. Presentation of Test Results

The results will be presented as shown in figure 10. The presentation is designed to reflect the purpose of the test: to demonstrate equivalent performance of the display operating with primary (baseline test) vs. secondary refrigerants. The upper three curves show the response of the package temperatures to this change (WTPA, IAT, CTPA). The fourth curve represents the temperature of secondary fluid existing display case. The last curve represents the reduced average load for the overall period (Q_{oa}). Q_{oa} is influenced by the defrost time. Unlike for the baseline test, the test level will be determined by the temperature of secondary fluid entering the display case (Trin).

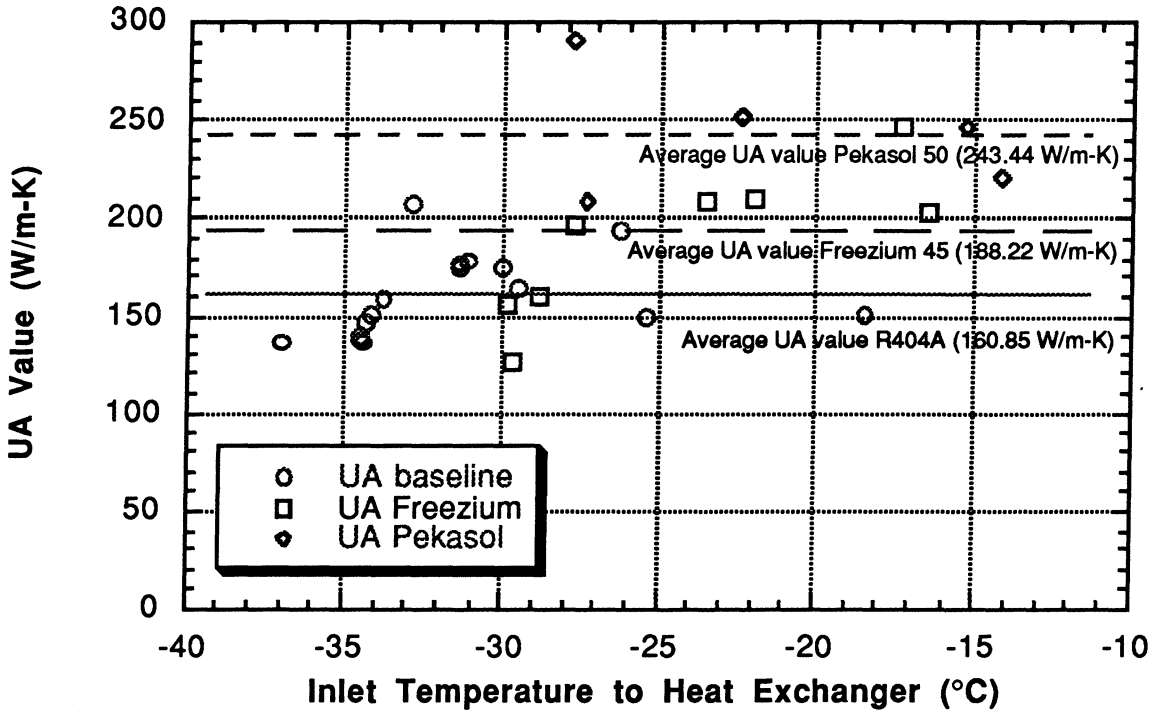

Figure A5-2. UA values for various test runs (Baseline and Secondary Fluids)

Appendix 6

Heat Exchanger Dimensions

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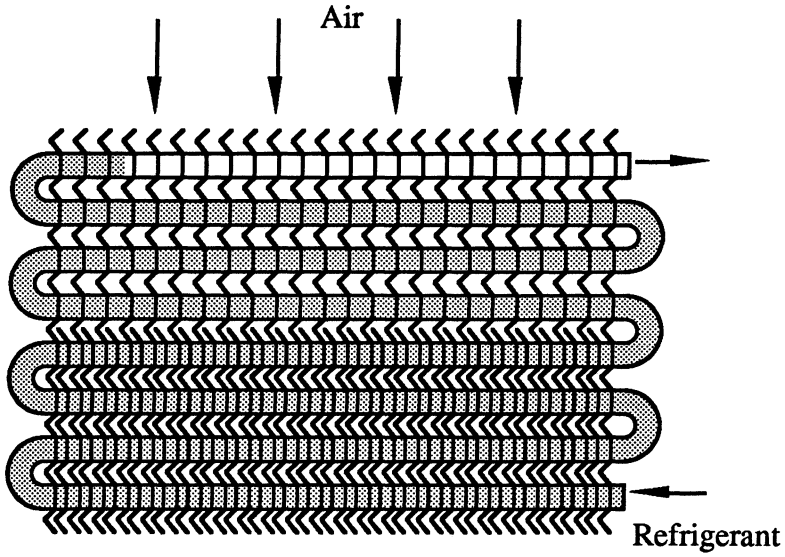

Figure A6-1. Overhead view of Heat Exchanger
(Note: first half of heat exchanger fin density is twice of second half)

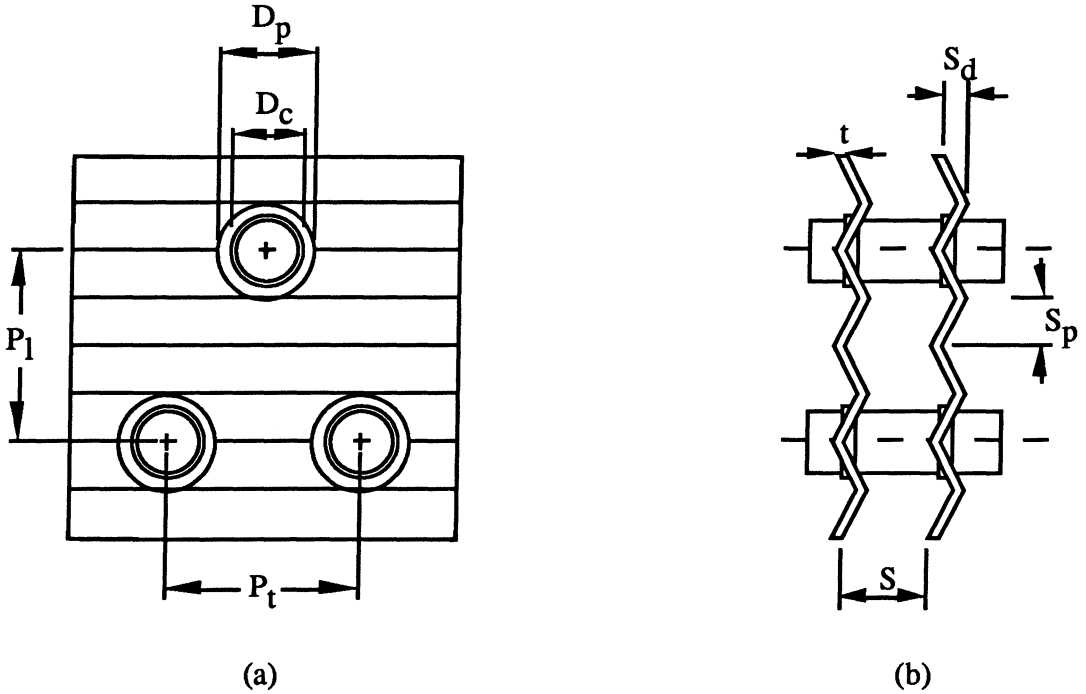

Figure A6-2. Dimensions of Heat Exchanger

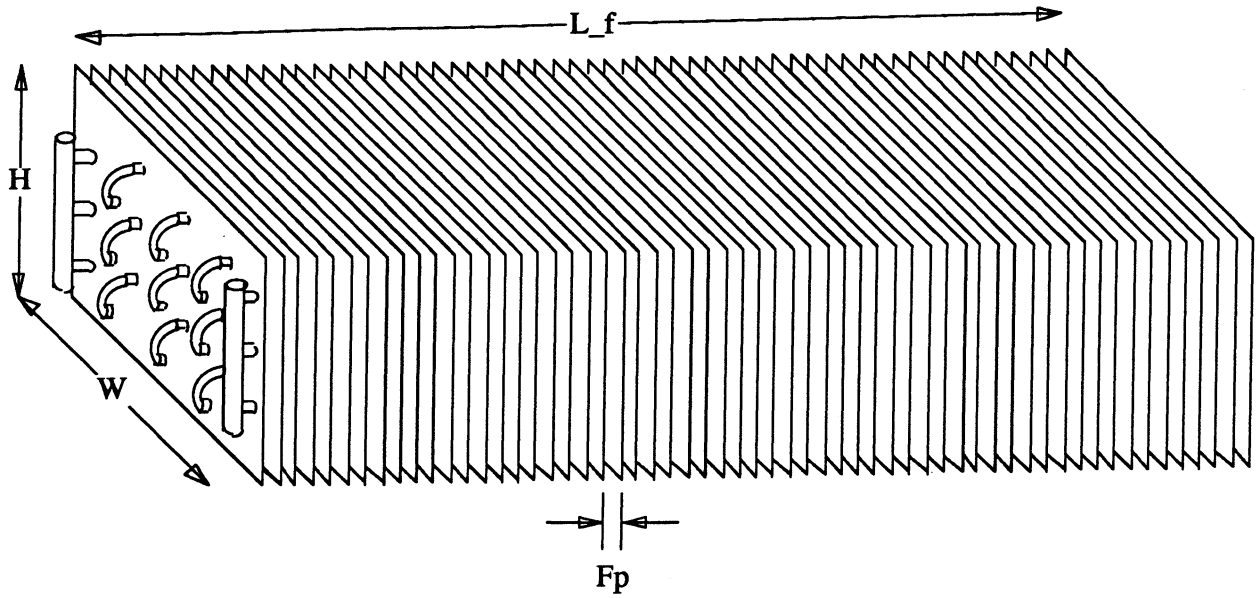

Figure A6-3. Dimensions of Heat Exchanger

Variable	Parameter	Value
inlets	number of refrigerant inlets	3
Nt	number of tube rows transverse to air flow direction	3
Nl	number of tube rows in air flow direction	8
L_t	length of tubes in heat exchanger (80 inches per pass)	2.032 {m}
L_f	length of finned portion of heat exchanger	2 {m}
Pl	tube spacing in air flow direction, 1.25 inches	0.03175 {m}
Pt	tube spacing transverse to air flow direction, 1.62 inches	0.03810 {m}
S_1	fin spacing for first half of heat exchanger, 1/Fp_1	0.00631 {m}
Fp_1	fin pitch for first half of heat exchanger, 322 fins/80 inches	158.46 {#fins/m}
S_2	fin spacing for second half of heat exchanger, 1/Fp_2	0.01262 {m}
Fp_2	fin pitch for second half of heat exchanger, 161 fins/80 inches	79.23 {#fins/m}
t	fin thickness	0.0002 {m}
D.in	inner diameter of refrigerant pipe	0.01092 {m}
D.out	outer diameter of refrigerant pipe, 0.65 inch	0.01270 {m}
S_p	one-half wave length of fins	0.00794 {m}
S_d	peak-to-valley wave depth of fins	0.0008 {m}
Dc	fin collar diameter	0.1310 {m}

Table A6-1. List of Dimensions of Heat Exchanger